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NEIC Manual for Groundwater/Subsurface Investigations at Hazardous Waste Sites

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The manual presents a systematic approach to conducting groundwater/subsurface (hydrogeologic) investigations at hazardous waste sites. The procedures include obtaining background information, inspecting and monitoring the site, and installing monitoring wells. Suggested information gathering activities are proposed and major considerations for designing and/or evaluating a monitoring well network are presented. The subject areas and information types are not prioritized because each groundwater pollution problem occurs in a unique hydrogeologic setting. By considering the potential data use in each subject area and the characteristics of the site under study, the investigator determines the types and extent of information required to define a particular pollution problem.

Also included are seven appendices that describe sources of hydrogeologic and other relevant data, fundamentals of groundwater hydrology, procedures for well drilling and equipment for borehole air sampling. More than 80 cited and bibliographic references are presented.

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NEIC MANUAL FOR GROUNDWATER/SUBSURFACE INVESTIGATIONS AT HAZARDOUS WASTE SITES

July 1981

Steven W. Sisk

NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
Denver, Colorado

DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

This manual presents major information needs and procedures for conducting groundwater/subsurface investigations at hazardous waste sites, including considerations for installing permanent monitoring wells. It is written for users who have a working knowledge of environmental investigations.

To make this manual as useful as possible, it will be periodically updated and revised.

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I. INTRODUCTION

PURPOSE AND SCOPE

The National Enforcement Investigations Center (NEIC) is increasingly called upon to investigate hazardous waste disposal sites (HWSs) with emphasis on assessing pollutant movement in the subsurface. Personnel formerly engaged in other aspects of environmental monitoring now find themselves trying to unravel the "mysteries" of groundwater flow. For these reasons, a need has arisen to define and describe procedures for conducting groundwater/subsurface investigations at HWSs. This document addresses that need.

Groundwater/subsurface investigations require gathering information primarily in the areas of hydrology and geology. The relatively new discipline that addresses both these fields is hydrogeology. This manual provides guidance and identifies available information sources for conducting hydrogeologic investigations at HWSs. Other literature discussing hazardous waste site evaluations is available.[53,61]*

APPLICATION OF HYDROGEOLOGIC STUDIES

In general, hydrogeologic studies range from exploratory to interpretive. Exploratory or "detective" monitoring establishes the presence or absence of contaminants and the need for more comprehensive monitoring. By contrast, interpretive monitoring determines damage extent and defines potential remedial actions. NEIC surveys are typically exploratory, often resulting in interpretive studies conducted by others with NEIC overview. This distinction is made to establish the target of NEIC investigations and to emphasize the need for clearly defined objectives.

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* ***References cited in the text are not in chronological order. The "Literature Sources," which follows the narrative, includes both text and bibliographic references alphabetized by author's last name.***

Defining study objectives is a fundamental step in any, including a hydrogeologic, investigation. Common objectives of HWS hydrogeologic studies include:

1. Identify the problem
2. Define the problem
3. Gather evidence for enforcement purposes
4. Evaluate remedial measures

NEIC field studies at HWSs usually address only the first three objectives. However, NEIC personnel are commonly involved in evaluating data developed by company personnel and/or consultants for the purpose of prescribing or undertaking remedial measures.

MANUAL FORMAT

The procedure followed by NEIC in any investigation is to conduct, in an orderly manner, various information collecting activities or steps. As data are collected and evaluated, the extent and magnitude of the pollution problem becomes more clearly defined. As the problem is defined, the need for additional data collection, enforcement action, and/or remedial measures can be determined.

The following chapters describe the activities which generally occur in evaluating groundwater/subsurface pollution problems at hazardous waste sites including:

1. Obtaining background information
2. Inspecting and evaluating the site
3. Site monitoring
4. Installing monitoring wells

In the chapters that address 1 through 3 above, the purpose of the activity is presented, followed by pertinent subject areas that are discussed in terms of potential data use and collection procedures. The final chapter addresses major considerations for designing and/or evaluating a monitoring well network.

The subject areas and information types are not prioritized because each groundwater pollution problem occurs in a unique hydrogeologic setting. By considering the potential data use in each subject area and the characteristics of the site under study, the investigator determines (usually with the aid of a hydrogeologist) the types and extent of information required to define a particular pollution problem.

Following the text are the appendices and literature sources. The seven appendices describe the locations of hydrogeologic and other relevant data, fundamentals of groundwater hydrology, procedures for well-drilling, and equipment for air sampling. More than 80 literature sources are presented in an alphabetical listing after Chapter V. All references are available to NEIC personnel through either the library or staff collections.

II. OBTAINING BACKGROUND INFORMATION

PURPOSE

Background information is that which is available or can be obtained from existing records. Research detail is governed by the extent of information and project scope. The initial objective is to define, with minimum resource expenditure, the probable magnitude of the pollution problem and the potential for legal action. Information obtained can often be used when planning and conducting field work and preparing the report; therefore, the review should be as thorough and accurate as possible. Preliminary background information collection could lead to:

1. Refinement of investigation objectives
2. Identification of data needs to meet the refined objectives
3. A plan for the site inspection and evaluation to fulfill needs
4. A resource base for conducting subsequent project activities

When an investigation begins, relevant data types and sources are seldom known; consequently, a variety of subject areas must be evaluated in regard to the study site to select appropriate research areas. Three major subject areas are discussed here as beginning points for information gathering: (a) cultural details, (b) hydrogeologic setting, and (c) safety considerations during field work. Sources of information discussed in this chapter are presented in Appendix A.

CULTURAL DETAILS

Cultural details are those related to man's activities as opposed to natural phenomena. This information is usually obtained from EPA regional offices, other Federal, state, and local government files, and Company (site owner, transporter, generator) records [Appendix A, Part 1]. The following are suggested data which should be gathered for any site, if available.

1. Land use in the area
2. Site use prior to waste disposal
3. Site preparation prior to waste disposal; identifying predisposal engineering or geological studies and records of soil tests
4. Types and volumes of wastes disposed of
5. Sources of waste
6. Chronology and location of waste disposal
7. Total active life of site
8. Approximate volume of waste present (total area and thickness)
9. Site ownership and relationship of owner(s) to waste source(s)
10. Permits and site approval correspondence
    a. Past and pending legal problems
    b. Citizen complaints
11. Established monitoring points and historical data
12. Records of catastrophic events (fires, explosions, floods, etc.)
13. Reported health problems attributed to the site
14. Location of buried utilities passing through site
15. Other potential sources of pollutants
16. Groundwater use in the area
17. Information on how the site was closed (if not active)

HYDROGEOLOGIC SETTING

To assess groundwater impacts from an HWS, there must be an understanding of how the waste deposit interacts with the surface and subsurface environments (hydrogeologic setting) in both space and time. The substance of the study is to assemble data for this assessment including site geology, hydrology, and climate.

The following discussion presents types of information that are gathered about the hydrogeologic setting. Information sources include published and unpublished literature, maps, computer data bases, personal contacts, and aerial photography [Appendix A].

Geology

Relevant geologic information includes regional and site specific data pertaining to both consolidated (bedrock) and unconsolidated formations. Those factors that affect water movement and quality are most important. If nothing is known about the geologic setting of the site, research stratigraphy first [Table 1]. If other geologic factors are of concern, stratigraphic information is likely to provide clues as to which are important. For example, if stratigraphy is complex due to faults and folds, "structural features" would be an appropriate subject to research. If certain formations are found to contain abundant lead-bearing minerals, then "mineral resources" should be researched. Judgment is exercised to determine the extent of information gathering in any subject area.

Site geology is often expressed in the surface topography as land forms because geologic structure is a dominant control factor in their evolution.[76] After identifying geologic features, plot them on the topographic map so the geologic setting can be related to observable land forms [Figure 1]. These land forms will be evaluated during the site visit regarding their potential to direct surface and/or subsurface water toward the disposal site [Figure 2].

Primary sources of geologic information are the U.S. and state Geological Surveys [Appendix A, Parts 2 and 6]. Much of the published literature is available from the USGS library in Golden, Colorado and from various USGS offices at the Denver Federal Center [Appendix A, Part 2].

Hydrology

Water transports pollutants from disposal sites into the surrounding environment [Figure 2]. Pertinent hydrologic information relates to transport water sources (i.e., rainfall and upgradient groundwater flow) and downgradient movement on the land surface or in the subsurface through permeable media. No single factor prevails at all sites; therefore, several characteristics of local hydrology must be assessed for their relative

Table 1

TYPES AND SOURCES OF GEOLOGIC INFORMATION

Topic	Definition and Sources
Stratigraphy	Stratigraphic data are formational designations, age, thickness, areal extent, composition, sequence, and correlations. Aquifers and confining formations are identified so that units likely to transport pollutants can be delineated. Lateral changes in formations (facies change) are noted if present. Information can be obtained from the USGS library in Golden and from major state university libraries, in addition to sources mentioned previously.
Structural Features	Structural features include folds, faults, joints/fractures, and interconnected voids (i.e., caves and lava tubes). Deformed, inclined, or broken rock formations can control topography, surface drainage, and groundwater recharge and flow. Joints and fractures are commonly major avenues of water transport and usually occur in parallel sets. Solution features such as enlarged joints, sinkholes, and caves are common in limestone rocks and promote rapid groundwater movement. Pertinent data on structural features would include type, compass orientation, dip direction and angle, and stratigraphy. Information can be obtained from the sources listed for "Stratigraphy".
Mineral Resources	Mineral resources refer to commercial deposits of minerals, quarry rock, sand/gravel, oil and gas. Such deposits near the study area are identified and located. These may represent pollutant sources to be considered when planning a sampling survey. Mines and quarries can often be used for direct examination of otherwise unexposed subsurface materials. USGS topographic maps show most mines/quarries and oil fields. Aerial photographs and ground level pictures from USGS studies can be helpful in identifying and locating these features [Appendix A, Parts 2 and 3]. County soil surveys published by the U.S. Department of Agriculture are useful because they are printed as overlays on aerial photographs. They are available through state conservation offices [Appendix A, Part 5]. Other published and unpublished literature is available from sources listed for "Stratigraphy".
Seismic Activity	In active seismic zones, disposal site covers and liners may prematurely fail due to earth movement along faults. For this reason, fault locations and the seismic history of the study area are determined. A telephone call to the state geological survey is recommended as the first step when seeking this type of information [Appendix A, Part 6].
Formation Origins	Information about the origin of a deposit or formation (i.e., volcanic, metamorphic, stream-laid, etc.) gives clues to the hydrogeologist about structure, grain-size distribution (laterally and vertically), weathering, and permeabilities. Information can be obtained from sources listed for "Stratigraphy".
Weathering Profile	Bedrock and unconsolidated deposits, such as glacial till and windblown loess, develop characteristic weathering profiles. Zones in those profiles may be more permeable than others. The zones should be identified and characterized by composition and thickness. Weathering profiles for shallow depths (less than 10 ft) are usually presented in county soil survey maps and are discussed under "Mineral Resources".
Grain-size Distributions	Grain-size analysis, conducted on samples from unconsolidated formations, yields the proportion of material for a specified size range. Range distributions can be used to estimate permeabilities, design monitoring wells and enable the hydrologist to better interpret stratigraphy. Such analyses are most often performed during pre-construction engineering/soils studies for a site and may be obtained from local consulting firms in addition to other sources mentioned previously.

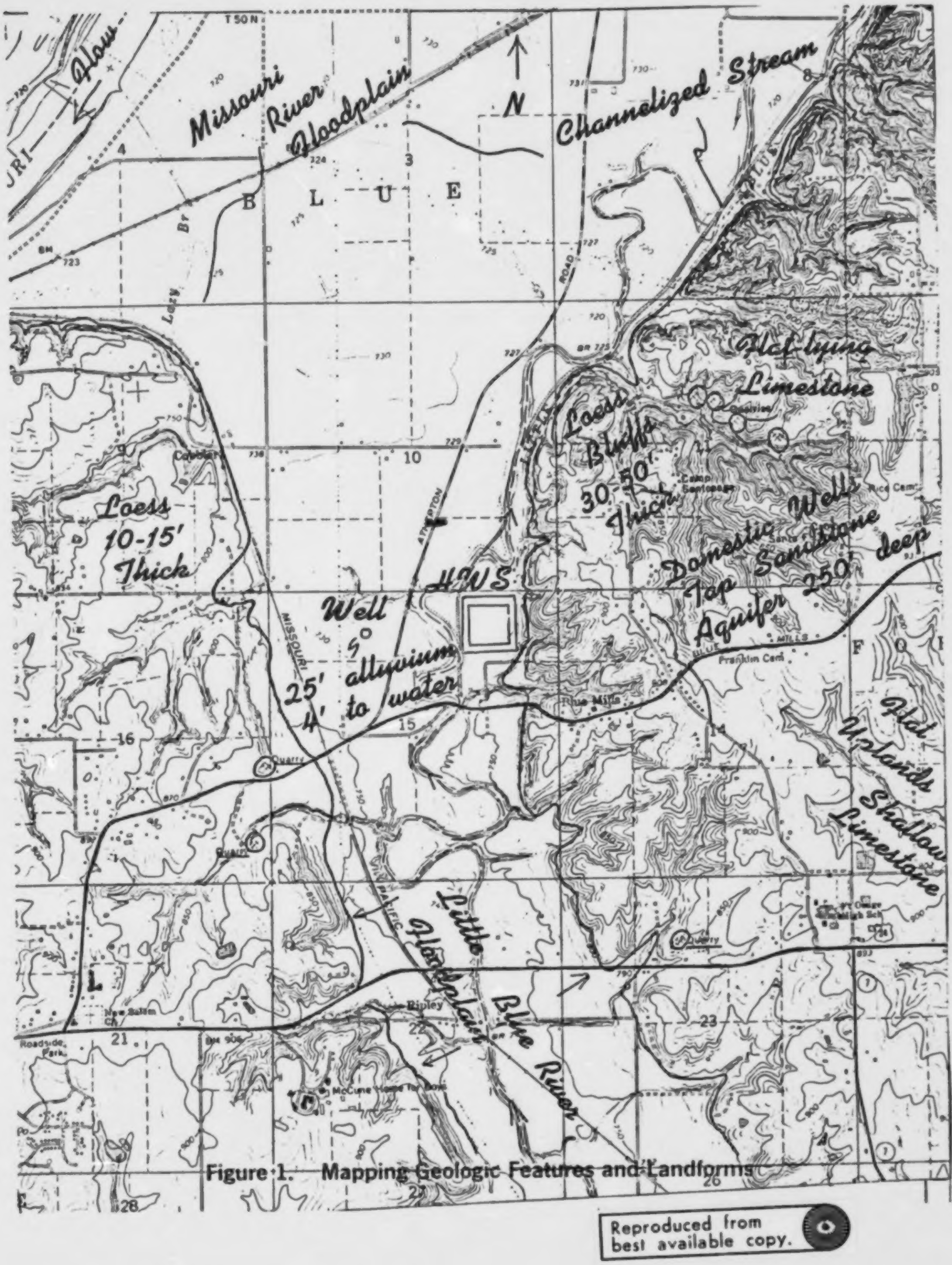
Flow
Missouri River Floodplain
T50N
N
Channelized Stream
B L U E
4
3
Loess 10-15' Thick
Loess Bluffs 30-50' Thick
Flat-lying Limestone
10
HWS
Well 5° 25' alluvium 4' to water
Domestic Wells Top Sandstone Aquifer 250' deep
Blue Mills
Franklin Cem
Quarry
16
15
Flat Uplands Shallow Limestone
Little Blue River Floodplain
Ripley
L
21
22
23
Roadside Park
McCune Home for Boys
28
27
26

Figure 1. Mapping Geologic Features and Landforms

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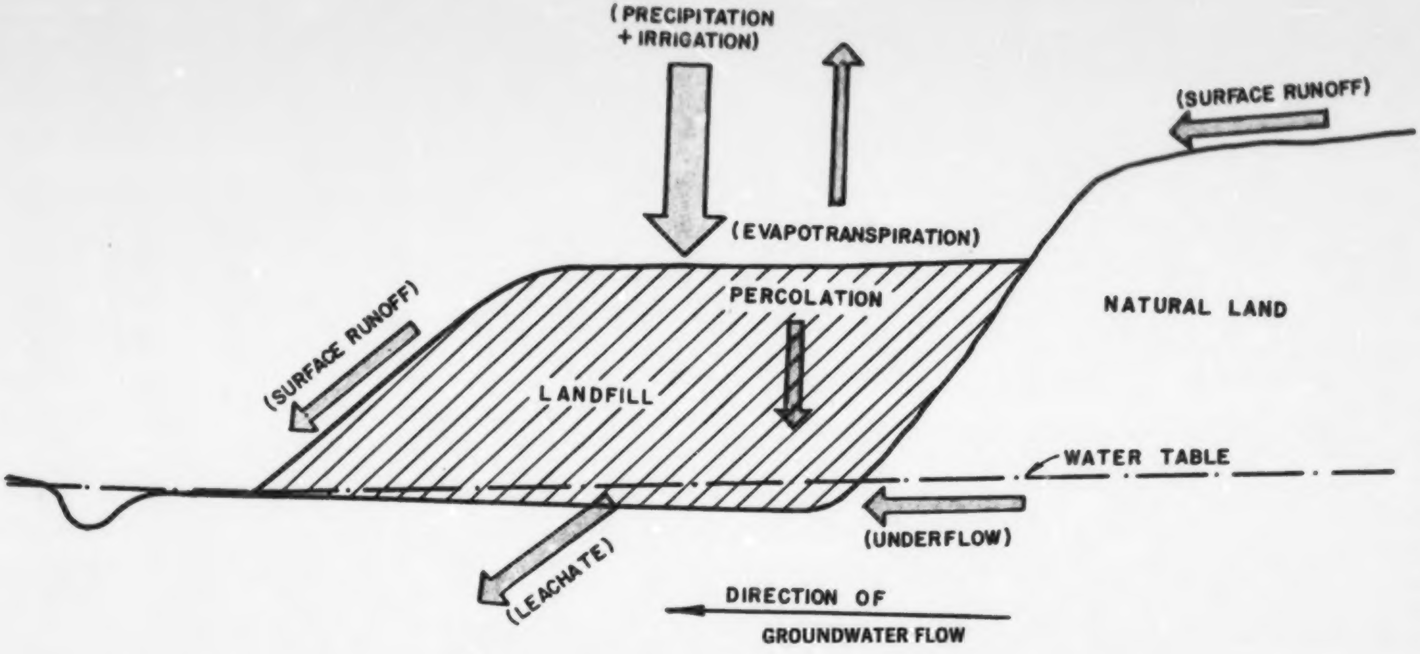
(PRECIPITATION
+ IRRIGATION)
(EVAPOTRANSPIRATION)
(SURFACE RUNOFF)
NATURAL LAND
PERCOLATION
(SURFACE RUNOFF)
LANDFILL
WATER TABLE
(UNDERFLOW)
(LEACHATE)
DIRECTION OF
GROUNDWATER FLOW

Figure 2. Simplified Landfill Water Balance

(From Reference 23, Figure 55)

importance [Table 2]. During an investigation, all topics presented in Table 2 should be addressed. Again, the investigator's judgment is required to determine the extent of data gathering on a particular subject.

Understanding groundwater hydrology involves creating a three-dimensional image of the site. As hydrogeologic data are gathered, draw vertical cross-sectional diagrams for visualizing subsurface conditions and identifying data deficiencies. Delineate waste deposits, geologic formations, aquifers, structures, and water tables or confined aquifer pressure surfaces (piezometric surfaces) [Figure 3].

Evaluating hydrologic data usually requires more specialized knowledge and experience than the geologic data because more judgment is needed. A basic understanding of the natural paths and rates of groundwater movement is important in evaluating groundwater pollution problems. A section on the fundamentals of groundwater hydrology, excerpted from a Princeton University training course manual, is presented in Appendix C. A more basic discussion on rocks and their water-bearing properties is presented in a publication by O. C. Meinzer.[47]

Climate

Climatic data, such as precipitation, temperature, wind movement, and evaporation potential, are essential background information. Precipitation records need to be complete enough to delineate seasonal trends which suggest periods of groundwater recharge. Temperature and wind data aid in evaluating airborne pollutant movement. Evaporation potentials enable calculation of subsurface water loss from waste liquid impoundments. Both pan and lake evaporation data have been compiled for most of the country. Recent climatic data can be obtained from the NEIC Technical Information staff and reference 6. Historical data are summarized in references 27 and 78 available at the USGS library in Golden [Appendix A, Part 2].

Table 2

TYPES AND SOURCES OF HYDROLOGIC INFORMATION

Topic	Definition and Sources
Surface Drainage	Surface drainage information includes tributary relationships, stream widths, depths, channel elevations, and flow data. The nearest permanent gaging station and period of record are also determined. A USGS 7½ minute topographic map will show some of the necessary information. Gaging stations and flow data can be identified and obtained through USGS data bases [Appendix A, Part 2] and from the NEIC Technical Information staff.
Ground and Surface Water Relationships	Streams near HWSs can either receive groundwater inflow or lose water by channel exfiltration. Hydrologic literature is reviewed to determine if local streams are "gaining" or "losing". Losing streams are common in areas of limestone bedrock and those with arid climates and coarse-grained channel substrates. Potential groundwater recharge areas are also identified. Flat areas or depressions noted on the topographic are suspect, while steep slopes normally promote runoff. Stereo-pair aerial photographs can be useful in these determinations [Appendix I, Part 3]. Irrigated fields detected in aerial photographs suggest recharge areas; swampy, wet areas suggest areas of groundwater discharge.
Underlying Aquifers	Information is collected to delineate aquifer type (unconfined, confined, or perched), composition, boundaries, hydraulic properties (permeability, porosity, transmissivity, etc.), and interconnection with other aquifers (direction of leakage). These data are generally available through geological survey publications.
Depth to Groundwater	As used here, depth to groundwater refers to the vertical distance from the ground surface to the standing water level in a well. In a confined aquifer, the depth to water represents a point on a "piezometric" surface. The depths will limit the types of equipment that can be used for purging and sampling. Probable groundwater flow directions (both horizontal and vertical) are determined by comparing depths to water adjusted for estimated ground surface elevation. Data may be obtained from USGS and other data bases through the NEIC Technical Information staff and various records listed in Appendix A, Part 1.
Water/Waste Contact	Possible ways that water could contact wastes are researched to understand how pollutants are carried into the environment and for later consideration in designing remedial measures. Possibilities include: 1. Precipitation falling directly on wastes 2. Precipitation infiltrating through cover materials 3. Floodwater (determine flood frequencies and elevations, compare to waste elevation) 4. Groundwater (compare elevations of wastes and groundwater) Pertinent information may be obtained from various records listed in Appendix A, Part 1 and from data bases accessed by the NEIC Technical Information staff.
Water Quality	The quality of ground and surface water in an area will define, to a large extent, potential uses. Leachate from an HWS can degrade water quality to the extent that practical use is limited or terminated. Knowledge of natural or background water quality and water uses are required to assess leachate imports. The quality of surface waters is usually available from EPA, USGS, and state records [Appendix A, Part 1]. Groundwater data will probably be quite limited for any given area, but may be discussed through USGS Water Resources Division offices, state geological surveys [Appendix A, Parts 2 and 5], and County health departments.

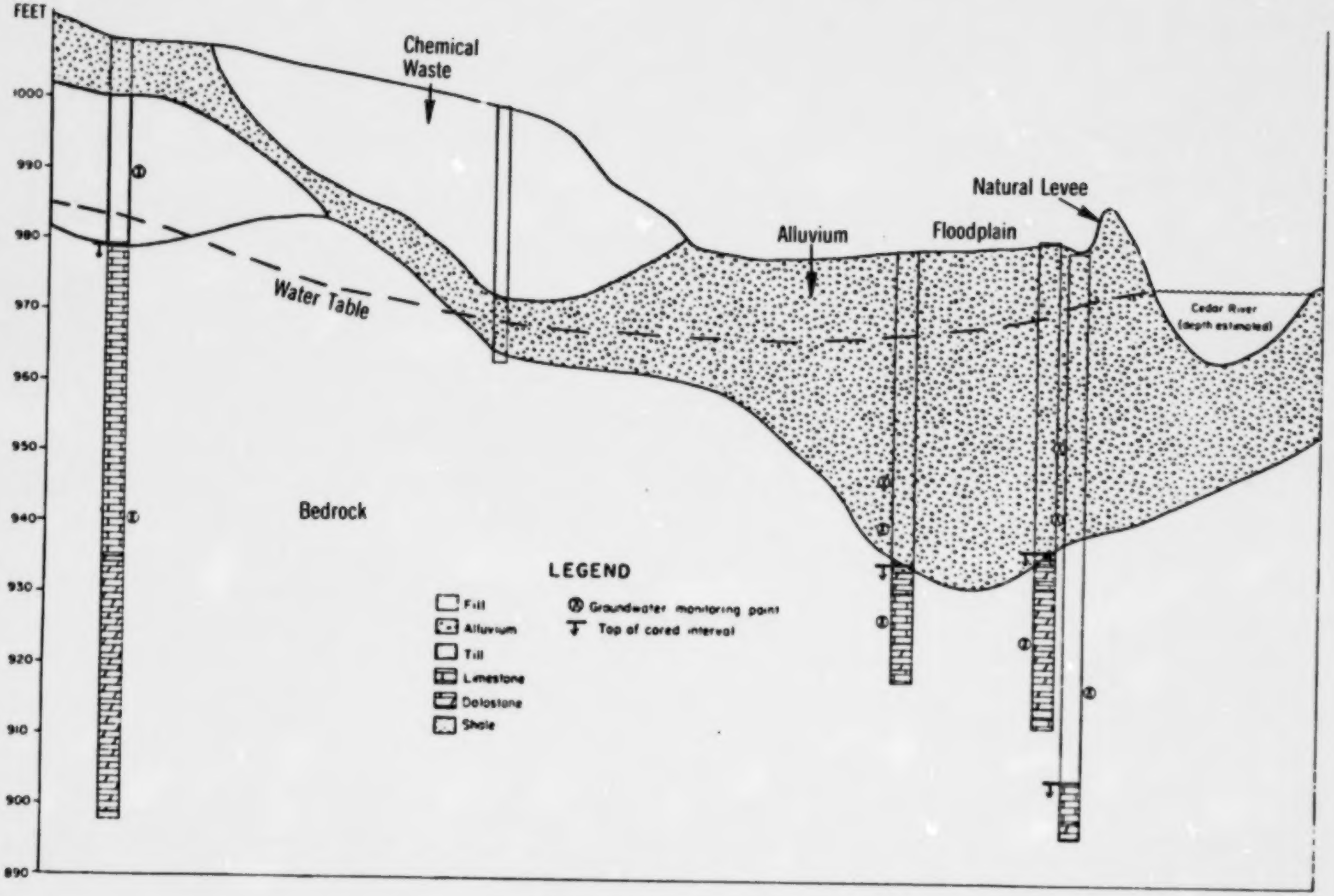
FEET
1000
990
980
970
960
950
940
930
920
910
900
890
Chemical Waste
Natural Levee
Alluvium
Floodplain
Cedar River (depth estimated)
Water Table
Bedrock
LEGEND
Fill
Alluvium
Till
Limestone
Dolostone
Shale
Groundwater monitoring point
Top of cored interval

Figure 3. Vertical Cross Section of a Hazardous Waste Site.

(After Munter, Iowa Geological Survey 1980)

SAFETY CONSIDERATIONS

Evaluating safety hazards is an important consideration in background research. Information on safety practices for HWS investigations is available in the literature.[56] Review health effects data for chemicals suspected to be present at the site so that "informed judgment" regarding safety can be ensured. Later, the information may be useful for assessing impacts. Hazard information and safety precautions will be especially critical if onsite drilling is necessary [Section V].

Health hazard information for chemicals is available from data bases accessed by the NEIC Technical Information staff [Appendix A, Part 4].[9,17,35,57,58,64,70,73,81] One suggested reference, the NIOSH/OSHA Pocket Guide to Chemical Hazards, presents recommended safety gear and potential health effects for 380 chemicals.[59] Similar information for more than 1,000 chemicals is contained in the OHM-TADS* data base which covers materials commonly encountered in industrial or transportation spill incidents.

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* *Oil and Hazardous Materials - Technical Assistance Data System.*

III. INSPECTING AND EVALUATING THE SITE

PURPOSE

Site inspection objectives are to expand the background information gathered on the site and to visually assess the potential for groundwater pollution. Information is gathered from persons, records, and site observations.

PRELIMINARY INFORMATION GATHERING

The first step in the onsite inspection is to contact responsible Company officials, if available, and conduct interviews for necessary information not previously obtained and to confirm that information from background research. Address any of the following that may be pertinent to the investigation:

1. Site operating history and ownership
2. Site layout
3. Waste sources
4. Waste handling
5. Waste storage
6. Waste treatment
7. Waste disposal practices
8. Past and pending legal actions regarding environmental problems
9. Any data the Company has generated regarding offsite migration of wastes

Review any available Company records for waste shipments, transporters, treatment, and disposal. Determine normal waste inventories, storage methods (drums, bulk tanks, rubber bladders, etc.), and storage areas to locate potential spill areas and identify past problems. Handle any confidential information supplied by the Company in accordance with the NEIC Policies and Procedures Manual.[54] The best policy is to accept confidential information only when absolutely necessary.

Identify and locate other nearby disposal areas and, if appropriate, inspect these other facilities. Potential sources of groundwater pollution in the vicinity of the site under investigation must also be identified and evaluated for a proper assessment.

SITE INSPECTION

Once preliminary site information has been assembled, visually examine the site with knowledgeable Company personnel, if available. Record observations in a project logbook and develop a site map. Plant drawings and/or aerial photographs are commonly used as a base for these maps. If no such base is available, draw a sketch using a compass and measuring tape or calibrated rangefinder. If possible, adjust the compass for the magnetic declination of the area so that the resultant map will be directly comparable to published maps and other drawings.

Take photographs at various locations to document conditions and provide visual proof of potential hazards. Obtain permission from the facility representative to take photographs and enter the appropriate information about each picture in a project logbook.[54]

Many features observable during the site visit may relate directly to the groundwater pollution problem. The investigator must understand the potential significance of features, such as those presented in the following subsections, and make proper note of each. Field observations can then later be discussed with a hydrogeologist to develop an assessment of the potential pollution problem.

Geomorphic Features

As previously noted, geologic structure is a primary factor in land form evolution. Also, the natural erosional or depositional history of a site can often be deduced from land forms. Identify common geomorphic features, when present, such as flood plains, stream terraces, glacial moraines, dunes, sinkholes, drainage divides, and valley profiles and mark their location on the site map.

Topography and Drainage Patterns

Topography and drainage observations aid in evaluating surface runoff, infiltration, and groundwater flow possibilities. Topography around the site governs surface water flow and suggests the probable direction of groundwater flow. Drainage patterns may indicate bedrock control, through joints or structures, which could influence groundwater flow [Figure 4].

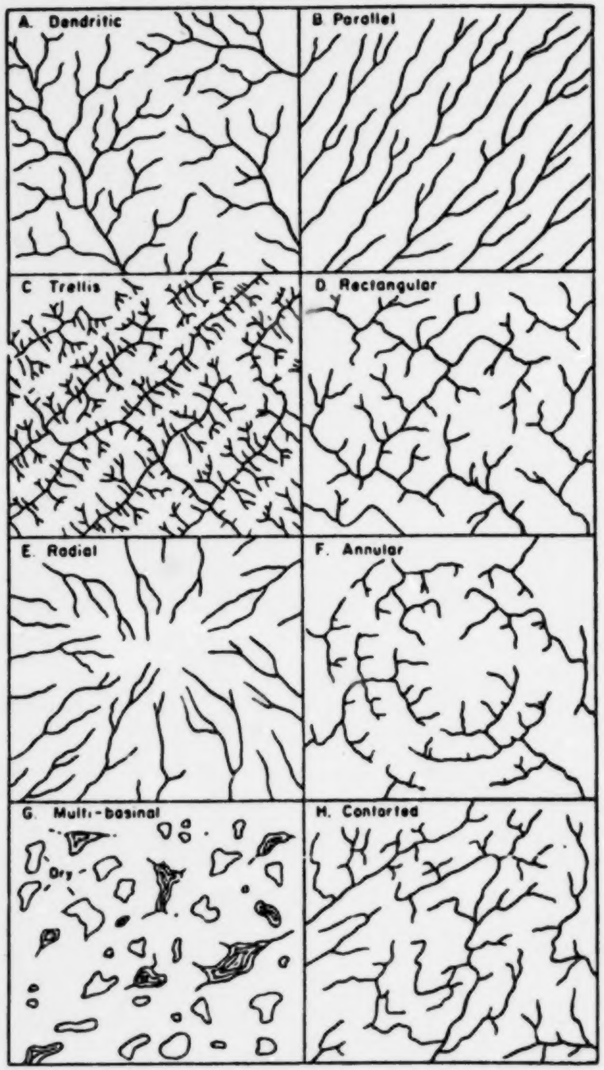
On the site map, indicate potential infiltration areas (i.e., flat areas underlain by permeable materials) and slope drainage toward stream channels. Identify drainage patterns and topographic relief on both a local and regional scale (usually from USGS 7½ minute topographic maps or aerial photographs).

Springs and Seeps

Springs and seeps represent groundwater discharge and are generally a result of the water table intersecting the land surface or of leakage from an artesian aquifer. Locate any such feature on the site map and describe both the physical characteristics of the flow (i.e., color and odor) and the materials from which it emanates. Determine the discharge flow rate using direct methods if possible.[5]

Surface Water Bodies

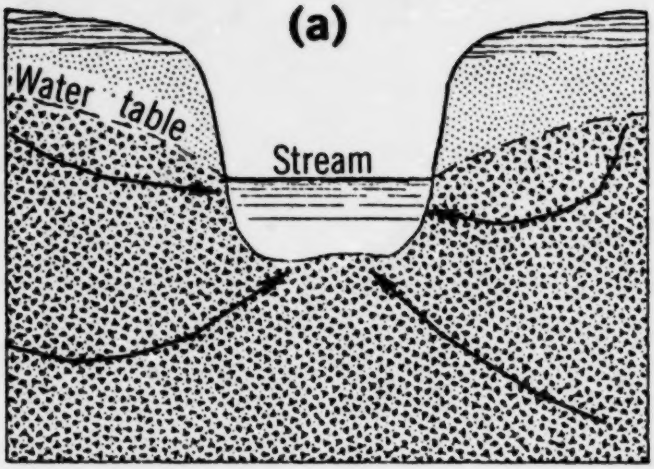
Surface water bodies, such as streams and impoundments, may be contributing to or receiving groundwater flow [Figure 5]. Their importance in this regard must be evaluated. Locate streams, rivers, and/or impoundments located within 0.5 mile of the site and describe them in terms of physical dimensions, source waters, and topographic relation to the HWS. Obtain and use available water level records for the identified surface water bodies together with groundwater elevation data to predict the direction of groundwater flow and pollutant movement. Access to stream and impoundment monitoring locations and records is presented in Appendix A, Part 2.



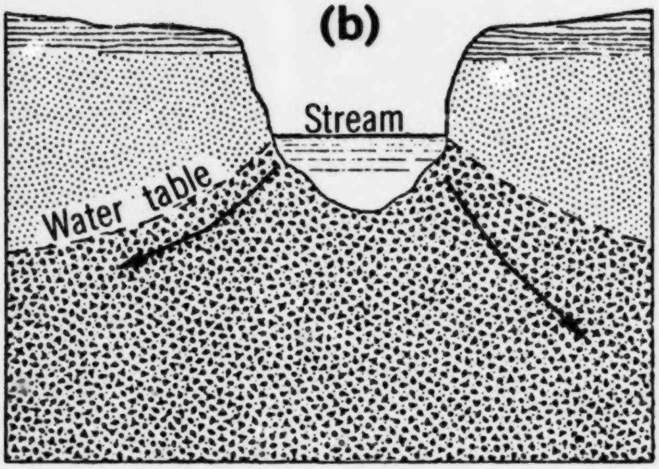
A. Dendritic occurs on rocks of uniform resistance to erosion and on gentle regional slopes.
B. Parallel occurs on steep regional slopes.
C. Trellis occurs in areas of folded rocks with major divides formed along outcrops of resistant rocks and valleys on easily eroded rocks.
D. Rectangular occurs in areas where joints and faults intersect at right angle.
E. Radial occurs on flanks of domes and volcanoes where there is no effect of differing rock resistance.
F. Annular occurs on eroded structural domes and basins, where resistant outcrops form major divides and weak rocks form valleys (a concentric type of trellis pattern).
G. Multi-basinal occurs in areas where the original drainage pattern has been disrupted by glaciation, recent volcanism, limestone solution, or permafrost.
H. Contorted occurs in areas of complex geology where dikes veins, faults or metamorphic rocks control the pattern.
The fishhook pattern of the main stream might also result from capture of a northeast flowing stream by the southward flowing main stream.

Source: A. D. Howard, *Drainage Analysis in Geologic Interpretation: A Summation*, AAPG Bull. 1967

Figure 4. Basic Drainage Patterns


(a)
Water table
Stream

Effluent streams gain water because the water table is above the stream level.


(b)
Stream
Water table

Influent streams lose water to the aquifer because the stream level is higher than the water table.

Figure 5. Effluent and Influent Streams

(From Reference 40, Figure 3)

Surficial Materials

Groundwater recharge from infiltrating precipitation depends on the permeability of surficial materials and rainfall intensity. General soils information is found in USDA County Soils Maps [Appendix A, Part 5]. Examine surficial materials at several representative locations and classify them by grain size and degree of sorting, as a minimum. A shallow hole excavated by shovel or hand auger is desirable to obtain suitable samples for examination. Use the following table as a guide for describing grain sizes.

Table 3

GRAIN SIZE CLASSIFICATION

Classification	Grain Size (mm)	Grain Size (in.)	Common Reference
Gravel	>2	>0.08	1/10 in. or larger
Very coarse sand	1 to 2	0.04 to 0.08	
Coarse sand	1/2 to 1	0.02 to 0.04	Sand grains visible to unaided eye
Medium sand	1/4 to 1/2	0.01 to 0.02	
Fine sand	1/8 to 1/4	0.005 to 0.01	
Very fine sand	1/16 to 1/8	0.002 to 0.005	
Silt	1/256 to 1/16	0.00015 to less than 0.002	Grains not visible to unaided eye
Clay	<1/256	<0.00015	

Distinguish silts and clays using a 10x hand lens; if fine grains are visible, the material is probably silt. Describe grain size mixtures by using subordinate fraction names as modifiers for the dominant fraction (i.e., silty sand). Denote the range in grain sizes by descriptors ranging from "poorly" to "well" sorted, depending on the degree of uniformity. Describe other features such as color, plasticity, organic content, and dessication cracks. Determine colors through comparison with standard soil color charts.*

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* *Munsell Soil Color Charts, MacBeth Division, 2441 North Calvent Street, Baltimore, Md. 21218*

Bedrock Outcrops

Locate bedrock outcrops on the site map, record the physical dimensions, and identify the rock type. Also measure major joint trends and formational strike and dip (if discernible) with a pocket transit. Methods for making these measurements are presented in reference 12. If rock identification is not possible, collect samples of each rock type, label properly, and photograph the outcrop. Proper labeling involves recording the vertical position in the section in a project logbook and keying the information to a sample tag affixed to the specimen and/or sample bag. Handle the sample under normal chain-of-custody procedures.[54]

Onsite Wells and Depth to Groundwater

Onsite or nearby wells are potential groundwater monitoring points. To the extent possible, collect construction information about any well identified during the site inspection.

Some minimal detail that should be collected includes data on screened or open intervals, construction and plumbing materials, total well depth, and water level. The screened or open interval is obtained from drilling records; direct methods are normally impractical. Complete construction details are necessary for any well used in a permanent monitoring network.*

Total well depth is also taken from drilling records; check by actual field measurements, if practical. Well depths from drilling records often exceed actual depths due to aquifer invasion through the screen or open-hole sloughing below the casing. Because of the potential for equipment contamination, sound the well with a reusable weight attached to a disposable line. Slowly lower the weight into the well until the bottom is detected. With the line taut, mark the top of casing level on the line with waterproof ink. Recover the line and weight from the well and accurately measure the length of line below the mark. Discard the line and thoroughly clean the weight before reuse.* Next, measure the casing length above (or below) ground level and subtract (or add) to obtain well depth. When measuring potentially contaminated wells, wear appropriate safety gear to avoid skin contact with well water.

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* *Some data may be useful for estimating pollutant travel distances and the other interpretation without being used as evidence.*

Water level measurements are made in onsite wells during the inspection. Ideally, a production well is shut down at least overnight, or longer, before measuring the water level. Depths to water are normally measured with respect to the top of casing, as in well-depth determinations. Several methods are available including: (1) the electric sounder, (2) the chalked steel tape, and (3) the popper.

The electric sounder, although not the most accurate, is recommended for initial site work because of the minimal potential for equipment contamination and simplicity of use. Check the 5-ft graduations on the sounder line against a measuring tape at the beginning of each inspection trip and record corresponding values in a project logbook. About 1½ in. of sounder probe submergence is required to fully activate the meter.

The chalked steel tape is a more accurate device for measuring static water levels. Coat the lower 3 to 5 ft of a steel measuring tape on either side with either carpenter's chalk, ordinary blackboard chalk, or a dry (noncontaminated) soil which changes shade when it gets wet. Attach a weight to the lower end to keep the tape taut and lower it into the center of the well (condensate on the casing wall may prematurely wet the tape). Listen for a hollow "plopping" sound when the weight reaches water. Then lower the tape very slowly for at least another 6 in, preferably to an even foot mark. Next, carefully withdraw the tape from the well; determine water depth by subtracting the wetted length of tape from the total length in the well. In small-diameter wells, the volume of the weight may cause the water to rise by displacement. Thoroughly clean the wetted section of the tape and the weight before reuse with soap and water, followed by acetone and distilled water rinses.

---

* *Minimum cleaning comprises a soap and water wash followed by a distilled water rinse.*

The metal tape and popper is another simple and reliable method for measuring depth to water in wells more than 1.5 in. in diameter. The popper is a metal cylinder with a concave undersurface fastened to the end of the metal tape. Raise and drop the popper until it hits the water surface and makes a distinct "popping" sound. Adjust the tape length so that the popper just hits the water surface. Read the depth to water from the tape measure.

Record (or reference) the following information for each water level measurement:

1. Well identification
2. Location and elevation of the reference point
3. Elevation of ground surface with respect to the reference point
4. Date and time of measurement
5. Measured depth to water and procedure used
6. The aquifer or zone represented by reading
7. Time since most recent pumping
8. Persons making/witnessing measurement

If possible, or when the well is being considered for long-term monitoring, collect more detailed information such as that listed below. Information sources include the owner, driller, and drilling or well logs.

Critical Information

1. Location
2. Owner or his authorized representative (address and telephone number)
3. Well depth ("as built" and present)
4. Casing dimensions and material
5. Screen dimensions and material
6. Sealing material and methods in borehole above gravel pack
7. Gravel pack interval and materials, if applicable
8. Static water level

Secondary Information

9. Date constructed
10. Operation and maintenance problems
11. Description of water-bearing zone
12. Yield (normal discharge/day)
13. Specific capacity
14. Water quality (both qualitative and quantitative)
15. Water use
16. Pump information (type, horsepower, metered flow)

Probable Natural Direction of Groundwater Flow

Groundwater flows as a result of pressure (head) differentials; flow is toward the lower head. In general, groundwater flows from higher topographic areas toward surface water; however, site geology and/or heavily pumped wells can drastically affect flow direction [Figures 6 and 7].

In the field, determine head differentials in an aquifer by measuring water levels in observation wells. The wells should be constructed in a similar manner (i.e., same open interval) and tap the same aquifer zone or level.

Evidence of Spills or Leachate Pools

Spill areas represent potential pollutant sources for both surface water runoff and groundwater recharge. They can usually be identified by discolored, disturbed, or odorous soils, and through sparse or distressed vegetation. Photograph observed or suspected spill areas, locate such areas on the site map, and describe them in a project logbook. Do not allow spilled material or contaminated soils to contact the skin or clothing.

Vegetative Cover

Vegetative cover can yield information about both pollutant and groundwater movement. Chemical spills, leachate, and gas contamination may

NOTE: Leachate first moves into and flows with the groundwater in the upper aquifer. Some of the leachate eventually moves through the confining bed into the lower aquifer where it flows back beneath the landfill and away in the other direction.

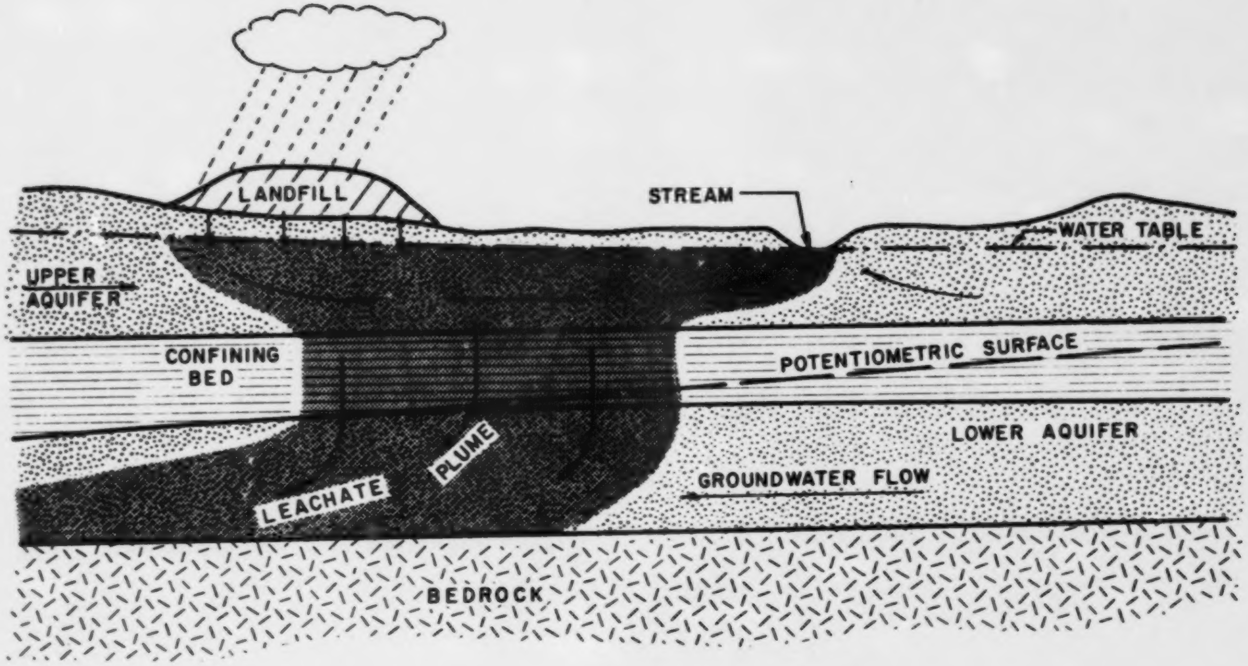
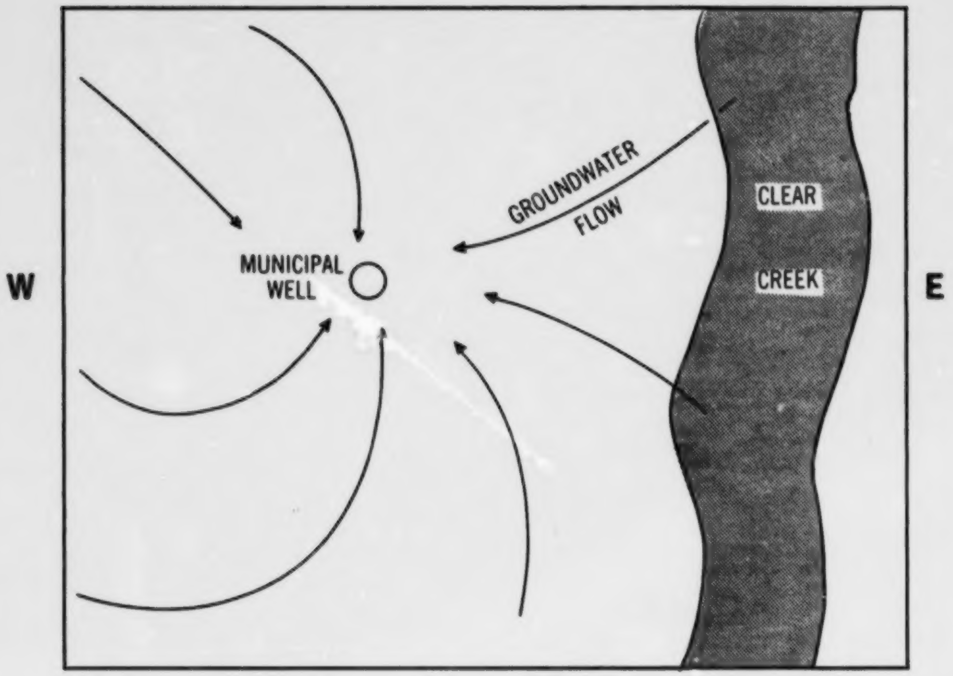
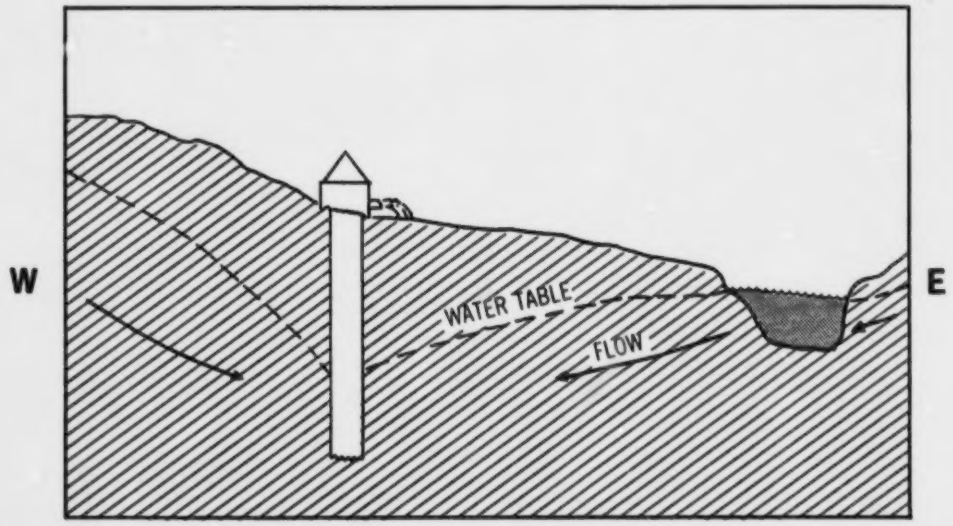

LANDFILL
STREAM
WATER TABLE
UPPER AQUIFER
CONFINING BED
POTENTIOMETRIC SURFACE
LOWER AQUIFER
PLUME
LEACHATE
GROUNDWATER FLOW
BEDROCK

Figure 6. Two-Aquifer System With Opposite Flow Directions

From Reference 23, Figure 23)


W
MUNICIPAL WELL
GROUNDWATER FLOW
CLEAR
CREEK
E

MAP VIEW


W
WATER TABLE
FLOW
E

VERTICAL CROSS SECTION

Figure 7. Groundwater Flow Affected by a Pumped Well

result in stress and/or destruction of vegetation at an HWS. The stressed areas can also indicate directions of gas or leachate movement, if not related to spills. The type of plants present can suggest the general availability of water, and special groups such as phreatophytes indicate groundwater depth. Naturally occurring phreatophyte trees, including ash, alder, willow, cottonwood, and aspen, generally grow where the water table is less than 9 m (30 ft) deep.[16]

Identify major vegetation types (i.e., trees, grass, brush, etc.), record evidence of stressed vegetation, and locate affected areas on the site map. Stressed vegetation can be mapped remotely by NEIC using aerial photographic methods [Appendix A, Part 3].

Dike, Liner, and Cover Materials

In general, evaluate the ability of dikes, liners, or cover materials to either contain the wastes and/or divert precipitation from contact with the waste materials. If natural materials are used for these purposes, describe them in the same manner as surficial materials, but include cover and liner thickness and dike dimensions. Identify the source area(s) for the materials and construction methods. Gather available design plans, specifications, and quality control data.

If special materials were used to line or cover the waste disposal area, such as asphalt, polymeric membranes, or chemically treated soils, determine the following data:

1. Composition
2. Thickness
3. Areal extent
4. Age
5. Application methods and quality control
6. Seam specifications for polymeric liners
7. Maintenance problems
8. Indications of precipitation or leachate penetration

Information on use of these special materials is presented in reference 30.

Good engineering practice for cover, dike, and liner installations is to conduct preliminary soil exploration work. If available, review exploration records for relevant details.

Buildings and Structures

As with dike and liner installations, major building and structure construction is normally preceded by soil exploration work, which could also yield pertinent subsurface information. If soil exploration work was conducted, obtain boring logs, location maps, and any results of soil testing.

Check foundations for settling cracks and basement seepage that might yield information about subsurface conditions such as areas of subsidence or shallow groundwater conditions.

IV. SITE MONITORING

PURPOSE

The objective of monitoring at an HWS is to identify or define the groundwater pollution problem. To achieve this objective, NEIC procedure is to conduct a multimedia study which often includes sampling pollutant source areas, groundwater, surface water, sediment, and air. Subjects and procedures discussed here deal specifically with direct and indirect indicators of both site hydrogeology and pollutant movement in the subsurface. Information on "above ground" monitoring procedures are available in the literature.[53]

GENERAL SAMPLING CONSIDERATIONS

Selecting chemical parameters for sample analysis is based on background research findings, the site evaluation, and discussions with laboratory personnel.* For sites where waste mixtures of unknown composition have been disposed, chemical analysis typically comprises a general organics scan, with emphasis on priority pollutants, other pesticides, metals, and anions. Mutagenicity testing and bioassays, with water fleas and fish, may be conducted to determine potential adverse effects on the living community. Table 4 (from reference 29) indicates major types of pollutants from various industrial and municipal sources that should be considered for monitoring.

Chemicals known to be in the disposed waste with demonstrated high mobilities can potentially be used as leachate plume tracers or indicators. Analyze for these parameters at all sampling points. Organic wastes tend to produce strongly reducing conditions that increase the solubility of the "non-mobile" chemicals until soil attenuation or oxidizing conditions remove them from solution. Therefore, plan waste source and close-in groundwater

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* *Any samples collected during an HWS investigation must be in accord with established chain-of-custody and document control procedures.*[54]

Table 4

CONSTITUENTS IN INDUSTRIAL AND MUNICIPAL WASTEWATER HAVING SIGNIFICANT POTENTIAL FOR GROUNDWATER CONTAMINATION

MINING (SIC 10, 11, and 12)

Metal and Coal Mining Industry (SIC 10, 11, and 12)

- pH
- Sulfate
- Nitrate
- Chloride
- Total Dissolved Solids
- Phosphate
- Copper
- Nickel
- Lead
- Zinc
- Tin
- Vanadium
- Radium
- Phenol
- Selenium
- Iron
- Chromium
- Cadmium
- Uranium
- Magnesium
- Silver
- Manganese
- Calcium
- Potassium
- Sodium
- Aluminum
- Gold
- Fluoride
- Cyanide

PAPER AND ALLIED PRODUCTS (SIC 26)

Pulp and Paper Industry (SIC 261 and 262)

- COD/BOD
- TOC
- pH
- Heavy metals
- Phenols
- Sulfite
- Color
- Biocides
- Nitrogen
- Phosphorus
- Total Diss. Solids

CHEMICALS AND ALLIED PRODUCTS (SIC 28)

Organic Chemicals Industry (SIC 286)

- COD/BOD
- pH
- Total Dissolved Solids
- Heavy metals
- Alkalinity
- TOC
- Total phosphorus
- Phenols
- Cyanide
- Total nitrogen

Inorganic Chemicals, Alkalies, and Chlorine Industry (SIC 281)

- Acidity/alkalinity
- Total dissolved solids
- Chloride
- Sulfate
- COD/BOD
- TOC
- Mercury
- Chlorinated benzenoids and polynuclear aromatics
- Phenols
- Fluoride
- Total phosphorus
- Cyanide
- Arsenic
- Chromium
- Lead
- Titanium
- Iron
- Aluminum
- Boron

CHEMICALS AND ALLIED PRODUCTS

Plastic Materials and Synthetics Industry (SIC 282)

- COD/BOD
- pH
- Phenols
- Total dissolved solids
- Sulfate
- Phosphorus
- Nitrate
- Organic nitrogen
- Chlorinated benzenoids and polynuclear aromatics
- Ammonia
- Cyanide
- Zinc
- Mercaptans

Nitrogen Fertilizer Industry (SIC 2873)

- Ammonia
- Chloride
- Sulfate
- Organic nitrogen compounds
- COD
- Iron, total

Nitrogen Fertilizer Industry (SIC 2873) (Cont.)

- Chromium
- Total dissolved solids
- Nitrate
- Zinc
- Calcium
- Sodium
- pH
- Phosphate

Phosphate Fertilizer Industry (SIC 2874)

- Calcium
- Dissolved solids
- Fluoride
- pH
- Phosphorus
- Acidity
- Aluminum
- Arsenic
- Iron
- Cadmium
- Mercury
- Nitrogen
- Sulfate
- Uranium
- Vanadium
- Radium

PETROLEUM AND COAL PRODUCTS (SIC 29)

Petroleum Refining Industry (SIC 291)

- Ammonia
- Chromium
- COD/BOD
- pH
- Phenols
- Sulfide
- Total dissolved solids
- Chloride
- Color
- Copper
- Cyanide
- Iron
- Lead
- Mercaptans
- Nitrogen
- Odor
- Total phosphorus
- Sulfate
- TOC
- Turbidity
- Zinc

PRIMARY METALS (SIC 33)

Steel Industry (SIC 331)

- pH
- Chloride
- Sulfate
- Ammonia
- Cyanide
- Phenols
- Iron
- Nickel
- Tin
- Chromium
- Zinc

ELECTRIC, GAS, AND SANITARY SERVICES (SIC 49)

Power Generation Industry (SIC 491)

- COD/BOD
- Polychlorinated biphenyls
- Total dissolved solids
- Oil and grease
- Copper
- Zinc
- Chromium
- Other corrosion inhibitors
- Phosphorus
- Organic biocides
- Sulfur dioxide
- Heat

Municipal Sewage Treatment (SIC 495)

- pH
- COD/BOD
- Alkalinity
- Detergents
- Total dissolved solids
- Nitrate
- Ammonia
- Chloride
- Sodium
- Potassium
- Sulfate
- Copper
- Tin
- Zinc
- Various Organics

sampling to be more comprehensive than elsewhere. By studying where certain pollutants are likely to be detected, and planning the study accordingly, the laboratory load can be decreased and data turnaround times can be improved without sacrificing thoroughness.

The potential fate of pollutants in surface water and sediment is also addressed when selecting analytical parameters. When groundwater discharges into flowing surface streams, the oxidizing environment will cause some pollutants to precipitate out of solution into the bottom sediments. In impoundments, they may be concentrated in stagnant stratified layers or bottom sediment.

Several references in the Literature Sources list can provide a starting point for mobility research.[2,8,13,14,24,29,36,42,46,61,69,80] Data base searches by the NEIC Technical Information staff can also supply pertinent information.

For many pollutants, ambient concentrations are very low, yet their presence in any measurable concentration may be significant. Procedures employed or materials contacting the sample should not cause pollutants to be gained or lost. Consequently, sampling equipment and sample containers are fabricated from inert materials and thoroughly cleaned before use. Thorough cleaning extends to drilling rigs, tools, and ancillary equipment which has a potential of imparting contaminants to the sample. Materials recommended for equipment contacting samples to be analyzed for organic compounds in order of preference, are as follows:

1. Glass
2. Teflon®
3. Stainless steel
4. High grade carbon steel
5. Polypropylene
6. Polyethylene

A common and proven effective cleaning procedure is to thoroughly wash the equipment with a laboratory-grade detergent followed by clean water, solvent, and distilled water rinses. Acetone is generally the recommended solvent. Sufficient time should be allowed for the solvent to evaporate before the final rinse as sample contamination problems have arisen from solvent/rinse water not drying completely before equipment use. Cleaned equipment surfaces may be protected with new aluminum foil if there is a potential for contamination between cleaning and use.

GROUNDWATER MONITORING

Accessible sampling stations, such as seeps, springs, and existing wells, are normally the first choices for groundwater monitoring. The paucity or absence of these points may require installing shallow-driven well points in some cases, depending on the water table depth and materials to be penetrated.*

During preliminary monitoring, choose points close to the disposal site to increase the chance of detecting leachate in groundwater. If appropriate, select points near property lines to document probable or actual offsite pollutant movement. Locate sampling stations both up- and down-gradient from the site to determine the extent of groundwater degradation.

Seeps and Springs

In the simplest cases, fill the sample containers either directly from the discharge or an adjacent downstream pool. Excavation, with thoroughly cleaned tools, may be required to form a pool of sufficient size. If excavation is required, allow solids stirred into suspension to settle or flush out before sampling.

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* *Comprehensive monitoring well networks are discussed in Section V.*

The following are suggested field measurements and observations.

1. Flow, if possible
2. Temperature
3. Conductivity
4. pH
5. Color
6. Odor
7. Explosivity of atmosphere above flow (explosivity meter)
8. Volatile gas release (HNU® meter)

These determinations will also enable the investigator to decide whether the samples are "hazardous" or "environmental" for shipping purposes.

Existing Wells

As previously noted, up- and down-gradient monitoring stations are important to the hydrogeologic investigation. Because more data points are required for plume definition, sampling emphasis is on down-gradient wells. Ideally, these wells would be relatively close to the site because groundwater typically moves slowly. Sampling wells without benefit of minimal construction information [Chapter III] should be avoided. However, do not be overselective for initial sampling if the well is likely to tap an aquifer of concern.

Well sampling involves two steps (not necessarily with the same equipment):

1. Presample purge
2. Sample collection

The primary consideration is to obtain a representative sample of the groundwater body by guarding against mixing the sample with stagnant (standing) water in the well casing. In a nonpumped well, there will be little or no vertical mixing of the water, and stratification may occur. Water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. Stagnant water may contain foreign material inadvertently or deliberately introduced from the surface, resulting in unrepresentative data and misleading interpretations.

Considerations for presample purging include proper disposal of pumped liquid and calculation of adequate volumes. Because of the potential for further environmental contamination, planning for purge water disposal is a necessary part of well monitoring. Alternatives range from dumping it on the ground (not back down the well) to full containment, treatment, and disposal. If the well is believed to be contaminated, the best practice is to contain the purge water and store it until the water samples have been analyzed.* Once the contaminants are identified, appropriate treatment requirements can be determined.

Required purging, suggested by available literature, ranges from one to five casing volumes** with judgment input being a critical factor to ensure that pumping is not excessive. Leachate stratification in groundwater may occur, and excessive pumping can result in flow entering the well from outside the zone of interest. Purging, necessary before obtaining predominantly "fresh" groundwater, depends on:

1. the pump intake level
2. water-yielding ability (specific capacity) of the aquifer
3. well "openness" to the aquifer (well efficiency)[40]

Pumping is required to determine the latter two factors; therefore, during initial sampling, "rules of thumb" are followed while well performance information is gathered for future sampling.

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* *See "Containing and Disposing of Contaminated Materials" in Chapter V.*

** *The volume of water contained in the casing before pumping.*

Common well situations, initial purging, and sampling procedures are presented in Examples 1, 2, and 3. In each example, three casing volumes are pumped through the screen before sampling except when a pump/packer assembly is used. Procedures discussed may be modifed for specific analytical parameters, well designs, and pumping systems. Volatile organics, for example, may require special sampling techniques, sealed wells may prohibit depth and water level measurements, and ideal purging may be impractical. Investigators must exercise judgment when collecting samples and fully document the procedures used.

Driven Well Points

When existing groundwater sampling points are either inadequate or nonexistent, driven well points can sometimes be installed. In some instances, shallow augering equipment can be rented from a contractor's supply firm to enable deeper well point installations.

Generally, well points are installed in medium- to coarse-grained, unconsolidated sandy materials in shallow water table areas. They are usually placed near the disposal site or zones of groundwater discharge, such as along streams. For this method, a 1.25 in. diameter well point with a 60-gauze or 10-slot screen is recommended. The well point is attached to the same diameter pipe and driven to completion depth with a drive weight or sledge hammer [Figure 8]. Normally, the well point can be driven to about 10 ft, however, 30 ft depths have been reported. Advantages of this method are: (1) low cost, (2) installed by hand without need for drilling contractor, and (3) good seal between casing and aquifer can be expected with little or no leakage. The well points can be recovered, but reuse is not recommended due to cleaning problems. Example 4 presents the procedure suggested for driven well point installations.

A small continuous-flight power auger [Figure 9] can be used to bore down to the desired completion depth before the well point is driven. In loose, sandy soils, well point penetration is much easier and installation depths are increased. For more cohesive materials (i.e., sifts and clays),

Example 1: Sampling an Open Monitoring Well

Step 1 - Using clean equipment, sound well for total depth and water level, then calculate the fluid volume in the casing ("casing volume").

Step 2 - Determine depth to mid-point of screen or well section open to aquifer from casing top.

Step 3 - Consult Table 5 and select appropriate purging equipment. If an electric submersible pump with packer is chosen, go to step 10.

Step 4 - Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect or dispose of purged water in an acceptable manner. Lower purging device, as required, to maintain submergence.

Step 5 - If pumping, measure water level with an electric sounder in uniform drawdown increments of 15 to 30 second intervals. If bailing, measure water levels as needed for a good record.*

Step 6 - Measure rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques, such as pipe trajectory methods or constructing weir boxes, are presented in reference 5.

Step 7 - Observe peristaltic or vacuum pump intake for degassing "bubbles". If bubbles are abundant and the intake is fully submerged, these devices may not be suitable for collecting samples for volatile organics.

Step 8 - Purge a minimum of two casing volumes before sampling.

Step 9 - While pumping, lower intake to mid-screen or mid-open section depth and collect sample. If bailing, lower device to sampling level before filling (this requires other than a "bucket-type" bailer). Make field measurements listed on page IV-6.

Step 10 - (For pump and packer assembly only) Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screen or open section volume below the packer (whichever is greater) before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.

Step 11 - After sampling, monitor water level recovery (may not be appropriate with a packer/pump assembly).

---

* *These data may be used to compute aquifer transmissivity and other hydraulic characteristics. Discuss the data with a hydrogeologist for determining appropriate equations and calculation procedures.*

Example 2: Sampling an Infrequently Used Production Well

Step 1 - Determine well usage schedule. If during routine pumping more than three casing volumes are drawn, see Example 3, if not, go to Step 2.

Step 2 - Near the end of the longest shutdown period, sound the well for total depth and water level, then calculate casing volume.

Step 3 - For sampling, select a discharge point in the plumbing system as close to the well head as possible. If appropriate, calculate the volume of plumbing and appurtenances between the well head and sampling point.

Step 4 - Activate the pump with only the sampling point open for discharge. Collect or dispose of the purged water in an acceptable manner.

Step 5 - Measure drawdown with an electric sounder in uniform increments [15 to 30 cm (6 to 12 in.)] or 15 to 30 second time intervals. Adjust increments or intervals as required.*

Step 6 - Measure discharge rate frequently. A bucket and stopwatch are commonly used; other techniques are presented in reference 5.

Step 7 - Purge at least three casing volumes. Allow for plumbing volume if it is significant.

Step 8 - Collect samples and make field measurements listed on page IV-6.

Step 9 - Shut off pump and monitor water level recovery.

---

* *These data may be used to compute aquifer transmissivity and other hydraulic characteristics. Discuss the data with a hydrogeologist for determining appropriate equations and calculation procedures.*

Example 3: Sampling a Frequently Used Production Well

Step 1 - Determine well usage schedule including:

1) Periods when more than three casing volumes are drawn during continuous pumping, and
2) Longest period of pump shutdown

Step 2 - Near the end of the longest shutdown period, measure total well depth and water level, then calculate casing volume.

Step 3 - Select a discharge point in the plumbing system, as close to the well head as possible, for sampling. If appropriate, calculate the volume of plumbing and appurtenances between the well head and sampling point.

Step 4 - At the beginning of the selected pumping period, record startup time and verify discharge.

Step 5 - Measure drawdown with electric sounder in uniform increments [i.e., 15 to 30 cm (1 to 12 in.)] or 15 to 30 second intervals. Adjust increments or intervals as required.*

Step 6 - Determine discharge rate by direct methods, if possible. Indirect methods may also be used. Water loss during initial drawdown represents an estimate of the minimum pumping rate. Also, pump-rating curves can be used.

Step 7 - Allow sufficient time for at least three casing volumes to be purged, and for the plumbing volume, if significant.

Step 8 - Collect samples and make field measurements listed on page IV-6.

Step 9 - Measure water level recovery upon pump shutdown.

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* *These data may be used to compute aquifer transmissivity and other hydraulic characteristics. Discuss the data with a hydrogeologist for determining appropriate equations and calculation procedures.*

Table 5

PURGING EQUIPMENT SELECTION

Diameter Casing	Bailer	Peristaltic Pump	Vacuum Pump	Airlift	Diaphram "Trash" Pump	Submersible Diaphram Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-inch								
Water level <20 ft		X	X	X	X			
Water level >25 ft				X				
2-inch								
Water level <20 ft	X	X	X	X	X	X		
Water level >25 ft	X			X		X		
4-inch								
Water level <20 ft	X	X	X	X	X	X	X	X
Water level >25 ft	X			X		X	X	X
6-inch								
Water level <20 ft				X	X		X	X
Water level >25 ft				X			X	X
8-inch								
Water level <20 ft				X	X		X	X
Water level >20 ft				X			X	X

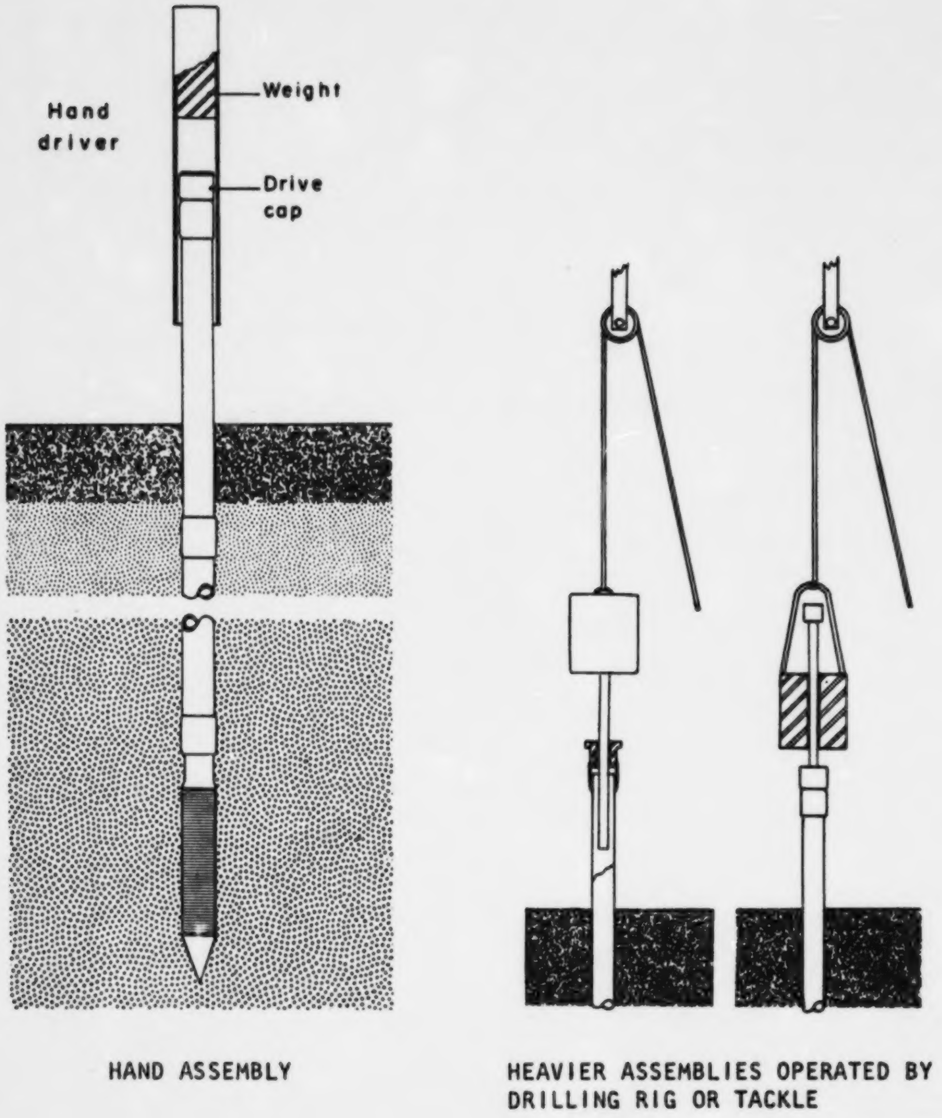
Hand driver
Weight
Drive cap
HAND ASSEMBLY
HEAVIER ASSEMBLIES OPERATED BY DRILLING RIG OR TACKLE

Figure 8. Methods for Installing Well Points

(From Reference 40, Figures 189 and 190)

Example 4: Procedure for Installing Driven Wellpoints

Step 1 - All tools, well points, and casing are thoroughly cleaned with detergent and solvent to remove dirt and cutting oils. Representative clean well points and casing are flushed with blank water (distilled-deionized), which is collected and analyzed. Care is taken to keep equipment and materials clean until used.

Step 2 - At the installation site, potentially contaminated surficial material and foliage are removed to a depth of not less than 6 in. and to a radius of not less than 1 ft to minimize the possibility of pollutant drag down from contaminated surficial materials.

Step 3 - With a hand auger, bore a hole slightly larger than the well point as deep as possible or to the water table, whichever is shallower.

Step 4 - Attach the well point to a length of casing (3 ft sections are recommended) and place in the augered hole.

Step 5 - Place a drive cap and driver on top of casing [Figure 5]. Drive well point, adding casing as needed, until the completion depth is reached, leaving at least 3 ft of "stickup" above ground level. Remove driver and drive cap. Pack wetted bentonite around casing into mound so that drainage is away from well.

Step 6 - Develop well, first with plunger then by pumping [Table 3] until water clears. Cover well with vented cap and secure to prevent tampering.

Step 7 - Allow well to stand at least 12 hours (overnight) before sampling so that water will rise to the water table level and any chemical reactions between groundwater and the casing can equilibrate.

Step 8 - After at least 12 hours, measure water level and purge well as in Example 1, page IV-9.

Step 9 - Collect sample and make field measurements listed on page IV-6.

Step 10 - Measure drawdown immediately after sample collection.

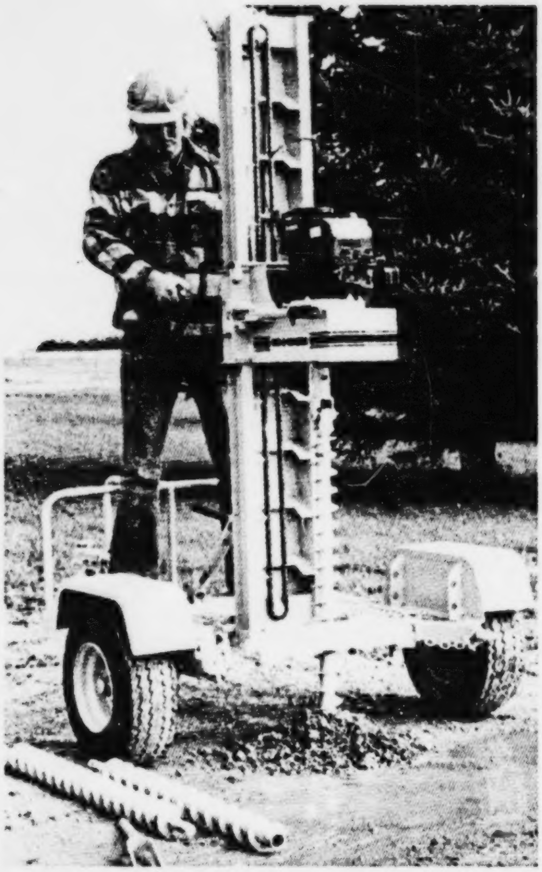

Figure 9. Small Continuous Flight Power Auger

(Photos courtesy of General Equipment Company)

the bore hole may stay open long enough to install the well point without driving. Once the well point is installed, finishing, developing, and sampling are the same as described above. The small power auger is relatively easy to operate and can be rented in most major metropolitan areas. Rented equipment should be thoroughly cleaned before use.

A do-it-yourself high-pressure car wash can be used for initial cleaning followed by solvent rinsing of the auger flights. Followup cleaning is required and the procedure will be dictated by the pollutant types expected to be encountered during drilling. If severe contamination is suspected, remove excess cuttings from the augers and rinse with clean water before transporting them offsite. Contain the cuttings and rinse water for proper disposal.

SURFACE WATER MONITORING

Surface water, including streams and impoundments, may receive contaminated groundwater flow or runoff. Surface water sampling can supplement groundwater monitoring or, in the absence of other monitoring points, be the most practical way of identifying offsite pollutant movement. Downgradient surface water suspected of receiving groundwater to flow should be sampled.

Streams

Properly planned stream sampling may reveal where the leachate plume enters the channel by comparing pollutant loadings for at least one upstream station and stations adjacent to and downstream from the HWS. Normal water quality variations across the stream dictate that flow-proportional samples be collected so that valid comparison of data can be made. Whenever practical, locate the stations in straight uniform stretches of channel with smooth bends and stable bottoms to enhance flow measurement accuracy.

At each station, the first step is to gage the stream using standard methods.[5] Next, divide the stream cross-section into equal-width subsections, depending on channel dimensions; a minimum of 10 is recommended. Flow proportional samples are then collected at the mid-point of each subsection. Inherent errors in flow measurements will result in different flow rates for each cross section. Unless significant (> 15%) increases in stream flow are present between stations (attributable to either a tributary stream or groundwater discharge), use only one flow value for computing loading. If one flow measurement is judged to be substantially better than the other, use it for loading computations. If the quality of all measurements is uniform, use an average for the stream flow value.

Impoundments

Impoundments are pooled bodies of water ranging from swamps and ponds to large reservoirs. As with streams, impoundments are of particular interest to HWS investigations when they are probable recipients of groundwater flow. Many impoundments reflect the water table surface in the area where they occur.

When monitoring is appropriate, sampling station locations and number will depend on:

1. likelihood of contamination
2. impoundment size
3. impoundment geometry
4. existing sample load
5. seasonal variations in impoundment conditions

The last factor, seasonal variations, is important because many lakes tend to destratify or overturn during the spring and fall months in areas where winter temperatures dip below 4° C (40° F).[25,83] Fewer samples, for example, will be required if overturn is occurring because this causes relatively complete mixing of impoundment contents. During other seasons, stratification will normally dictate additional sample collection.

Stratification in an impoundment is caused by density differentials due to variations in temperature, suspended silt, or dissolved substances; the denser water sinks to the bottom. Suspended or dissolved pollutants can increase water density or become trapped in a naturally stratified zone. Serious contamination, therefore, may not be apparent at the surface. For these reasons, collect samples at several points within a single vertical profile. Temperature and specific conductance measurements, made through continuous readings or taken at several depths, can often be used to quickly establish the depth and thickness of stratified layers.

Water sampling in lakes is normally done both near shore and offshore. Offshore locations are carefully triangulated with recognizable onshore map features so that monitoring points can be accurately plotted and located if repeated sampling is required.

The impoundment is also examined for signs of recent changes in pool level (e.g., submerged vegetation on high-water marks and terraces) that may have a bearing on the investigation. For example, a recently lowered pool level measured in conjunction with nearby well water levels could yield unrepresentative gradient and calculated groundwater flow rate.

Sediment

Sediment sampling in streams and lakes yields information on pollutant concentrations in bottom materials. This information documents the fate of various contaminants and the degree of environmental degradation in areas of contaminated groundwater discharges.

Impoundment sediment sampling stations are selected to represent materials at different locations and are not normally composited. As with water sampling, accurately locate the monitoring points for future reference. Concentrate sampling points in or near the area of probable contaminated groundwater discharge; however, establish control or background stations as conditions permit.

Generally, there are two types of sediment samplers: (1) bottom scrapers, such as scoops and dredges; and (2) bottom penetrators such as solid core tubes and split-spoon samplers. The nature of bottom materials and/or the survey purpose usually dictate the sample type. The bottom scraping samplers collect disturbed (relatively recently deposited) sediment while the coring devices collect relatively undisturbed samples representing longer periods of deposition.

AIR MONITORING

Air monitoring can sometimes be useful as a safety precaution during drilling and in determining the presence of volatile organics in boreholes and wells that could migrate in the subsurface. During drilling operations, use the HNU meter to monitor the borehole and cuttings for potentially dangerous gases to minimize the amount of protective gear worn by the drilling crew and others close to the rig [Appendix G].

Screening of the head space (air above the water level) in boreholes and wells can also be accomplished with the HNU meter. If vapors are detected, air samples should be collected. Sampling equipment often consists of a calibrated personnel monitor (vacuum source) connected, via an intake line, to a glass tube packed with Tenax®, a porous polymer resin [Appendix E].

V. INSTALLING MONITORING WELLS

PURPOSE

Every groundwater pollution investigation poses unique physical problems for designing and installing a monitoring well network, even in a framework of typical objectives. There are common factors for designing, installing, and using a groundwater monitoring system. This chapter addresses briefly some major considerations for either designing a network or evaluating one. In most cases, the situations discussed represent ideal conditions that may or may not apply to a particular project.

PURPOSE OF MONITORING WELLS

The usual purpose of a monitoring well network is to define groundwater quality and movement and to accomplish specific study objectives such as:

- To define the vertical and areal extent of the leachate plume
- To monitor pollutant concentrations
- To provide the means for detecting the leachate plume front, unexpected changes in size, or direction of flow
- To determine the extent of interaquifer movement of pollutants
- To determine aquifer characteristics (permeability, head distribution, transmissivity, etc.)
- To estimate rate of leachate plume movement
- To develop a data base for designing remedial measures
- To determine effects of remedial measures
- To assist in performing remedial work (leachate recovery)
- To provide data base for groundwater modelling

The objectives must be clearly defined and integrated at the outset since they will dictate fundamental design, such as whether monitoring stations will comprise a single well or a well nest.* They will also define where in the plume (top, middle, bottom, or outside) the wells must be located.

The evaluator must be able to recognize the ability of a particular network or plan to achieve the stated purposes or objectives. The key points to look for in study plans are specificity and reasonableness; the plan should fully explain how the objectives are to be met by the network, exactly how the wells will be installed, and the flexibility given to the field supervisor. For example, the plan should detail procedures for containing and disposing of contaminated cuttings. Disposal of the contaminated cuttings in a nearby stream is unreasonable. Errors, oversights, and misunderstandings can be reduced by following these two guidelines which must be used for writing plans as well as reviewing them.

PLANNING THE MONITORING NETWORK

Early in the planning phase, factors such as external requirements, data requisites, and well placement are considered to avoid shortcomings during the well design and installation phases. These three topics are presented here in a recommended order of consideration for a "typical" planning exercise. When evaluating plans, check to see that the variables indicated have been addressed.

External Requirements

External requirements or conditions are those that can affect well design and locations, over which the planner has no control. Three types of requirements and conditions normally researched include: 1) pertinent state, local, or other regulations; 2) permission to construct wells on private property; and 3) location of buried and above-ground utilities that might pose safety hazards to the drillers. Some of this information may have been gathered during earlier investigation activities as outlined in previous chapters of this manual. If not, begin gathering this information when the design process is initiated.

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* *Two or more wells, finished to different depths, usually installed in close proximity.*

Contact state and local governments* to determine if special permits, licenses, construction practices, or borehole closure procedures are required. Appendix B presents a summary of water well industry codes and licensing requirements for water well drillers. Also included is a list of state agencies and officials responsible for industry codes in 1976. State geological surveys [Appendix A, Part 6] and local drillers may also be able to supply appropriate information.

When drilling on private property, obtain easements from the owners or their authorized representatives. Any easement developed must be cleared through appropriate legal channels. Examples of easements (also called license agreements) which have been used by EPA are presented in Appendix F. Generally, the easements should:

1. protect the property owner,
2. protect the government or company,
3. be fair to both parties, and
4. be executed in good faith.

Locating buried utilities is normally done by contacting local electric, telephone, gas, water, and pipeline companies, and requesting appropriate information or service. To aid in making the proper contacts, the American Public Works Association periodically publishes a "One-Call Systems Directory" that lists contacts and telephone numbers to locate buried utilities in many geographical areas of the United States.**

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* *The Corps of Engineers regulates drilling and dredging activities along major water courses.*

** *The directory is available from the Utility Location and Coordination Council, 1313 East 60th Street, Chicago, Illinois 60637, 312/947-2520*

Data Requisites

The first four chapters discuss various activities for obtaining hydrogeologic information during a hazardous waste site investigation. This same information is used for planning, designing and installing a monitoring well network. As a minimum, assemble data for requisites presented in Table 6 from the file information. If critical information on these requisites has not been obtained, either estimates must be made or more data will have to be gathered. Installing monitoring wells and analyzing water samples are expensive, thus a concerted attempt must be made to gather real data whenever possible.

Well Placement

Determining the number and map location of groundwater monitoring sites are the first major tasks in the network design process. The next step is determining the vertical position of the well screens. During the planning process, attention must always be focused on the network purpose and objectives. Rather than stating specific procedures, several factors and concepts are considered for planning or evaluating a monitoring network.

In an ideal situation with one potential leachate source, a generally known groundwater flow direction, and an objective of identifying if problem exists, only two properly placed wells (one upgradient and one downgradient) would be needed [Figure 10a]. Even with a single leachate source and a simple objective, flow directions and proper locations are normally difficult to accurately determine. Consequently, more than two wells are usually installed to increase the probability of intercepting the plume [Figure 10b], collect adequate data, and be economical. Ultimately, the number of wells will depend on problem seriousness, hydrogeologic complexity, and available funds.

Table 6

DATA REQUISITES AND USES FOR PLANNING MONITORING WELL NETWORKS

Requisite	Use
Probable groundwater flow direction and expected seasonal changes	Use this information to locate areas for background (upgradient) wells and select those where intercepting the leachate plume is likely.
Location of other potential pollutant sources	In conjunction with information on groundwater flow directions, determine if and where pollutants from other sources might be detected in the study area.
Probable groundwater contaminants	Consider the chemical effects of the contaminated groundwater on potential casing materials (corrosion, adsorption, etc.), grout, and bentonite seals. Also determine if well design must accommodate special sampling procedures or equipment for these pollutants.
Expected range in depths to groundwater	Use these data to ensure proper well depths for year-round sampling. For water depths below about 20 ft, determine if well design must accommodate submersible pumps or other large down-the-hole equipment.
Types of materials to be drilled	Identify whether consolidated (rock), unconsolidated, or both types of formations will have to be penetrated so that the drilling rig alternatives can be determined. If unconsolidated formations are the only concern, find out if cobbles or boulders are common.
Probable geologic and hydrologic characteristics of the target formation and overlying materials	Use these data for selecting screen slot sizes, determining if a gravel pack is necessary, locating where the borehole should be sealed with grout or bentonite, and/or whether or not a surface casing should be set.
Available drilling equipment	Contact local drillers and identify the general availability of hollow-stem auger, hydraulic and air rotary, and cable tool drilling rigs in the area for establishing alternatives. Inquire about borehole diameter, depth capabilities, and costs.

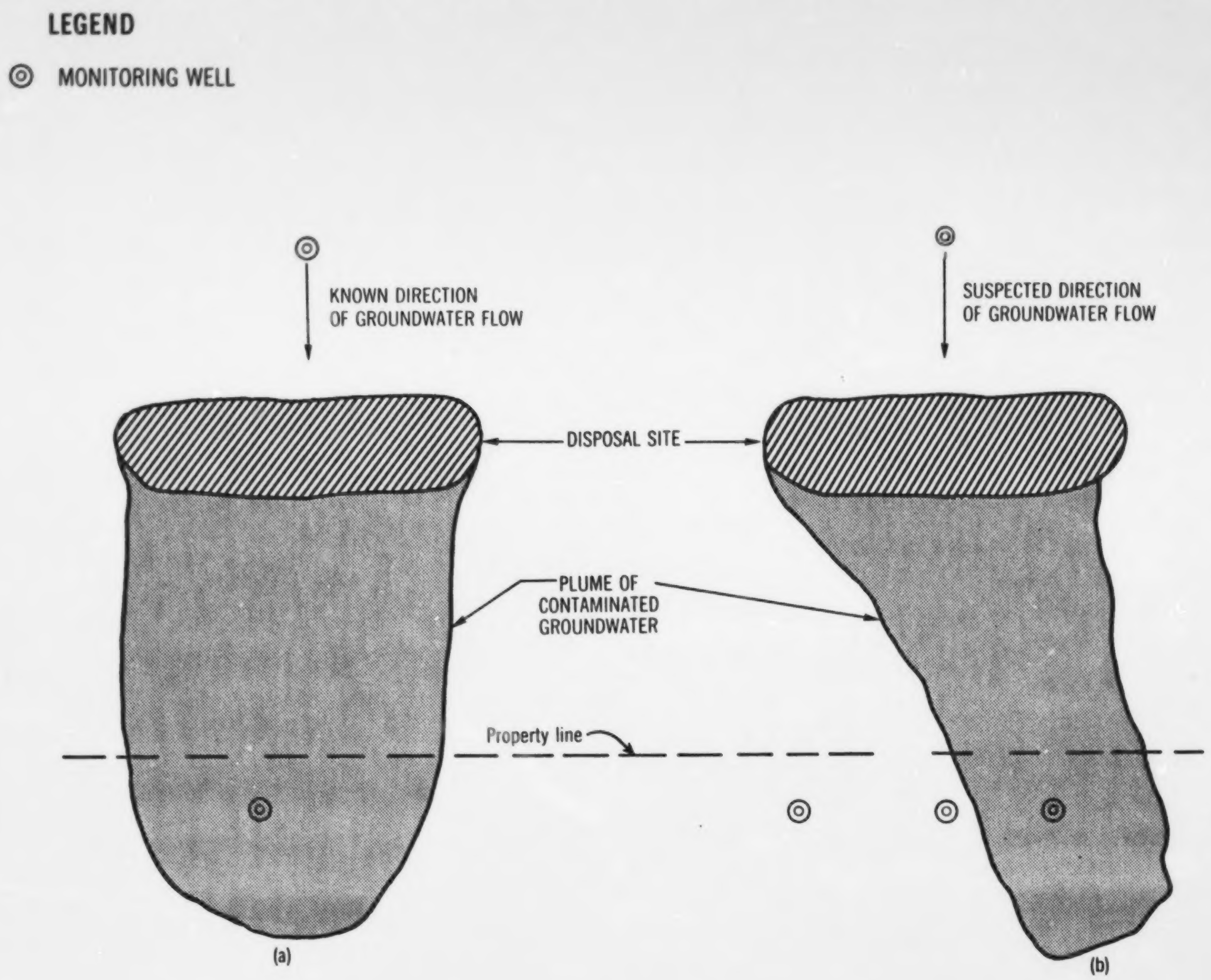
LEGEND
◎ MONITORING WELL
KNOWN DIRECTION OF GROUNDWATER FLOW
SUSPECTED DIRECTION OF GROUNDWATER FLOW
DISPOSAL SITE
PLUME OF CONTAMINATED GROUNDWATER
Property line
(a)
(b)

Figure 10. Well Locations for Problem Identification with Known and Suspected Groundwater Flow Directions in Plan View

(From Reference 23, Figure 6)

Wells should generally not be installed through fill materials until alternate methods of obtaining the desired information have been exhausted, for the following reasons:

1. Reactive materials could be united in the well bore to produce toxic gases, explosions, fires, or other potential hazards.
2. The borehole may create a conduit through which pollutants could move easily into the underlying aquifer.
3. Density stratification of leachate could produce nonrepresentative samples.

The purpose of such wells is usually to identify the waste composition, fill thickness, and nature of underlying materials. In many cases, however, waste deposit composition can be learned from background information and samples collected from shallow, hand-augered, or dug holes. The nature of underlying materials can be identified from perimeter borings.

Upgradient wells are critical for understanding leachate effects on water quality. Judgment is required in placing these wells for monitoring background conditions. They should be close to the fill or waste disposal area, yet out of the influence of the water table/leachate mound that often forms around HWSs. Not only will the mound affect "upgradient" water quality, but water table elevations in the mound will also be unrepresentative of ambient conditions. If multiple aquifers are of concern, there should be a background well for each.

Most monitoring sites will be downgradient from the waste deposit because more data points are required to define the leachate plume than to monitor background water quality. The recommended approach is to track the leachate plume outward from its source into the environment. Continuing success in tracking and locating the plume is more probable with this method.

Earth resistivity and shallow seismic surveys are frequently suggested for preliminary site studies aimed at locating leachate plumes and determining bedrock depths. In each method, the key to success is a high contrast between features of interest (e.g., conductivities of plume and background water and elastic properties of bedrock and overlying material).

If the contrast is minimal or clouded by complex geology and man-induced interferences (buried metal objects), then the techniques may not be applicable. Although these methods are valid and sometimes helpful, their use should be thoroughly justified. Results should always be confirmed with a representative amount of boring data; without adequate confirmation, the results are considered suspect.

In a typical groundwater pollution investigation setting, where the waste is underlain by unconsolidated alluvial materials with a free water table above bedrock, locate downgradient wells in an array that parallels the fill boundary. The first line of monitoring locations might be within 100 to 300 ft of the fill [Figure 11]. The second line is located by moving outward from the fill either on rays from the waste center through the first line of borings or where permeable or contaminated areas are suspected. Monitoring locations in areas near property lines is preferred for documenting offsite pollutant movement.

Grid-structured monitoring locations are generally not recommended because they are usually not cost effective and do not apply the planner's ability to interpret site hydrogeology.

Since leachate plumes are three dimensional, the vertical placement of the well screen is a major part of the planning process. Knowing the vertical position of the plume is important. Complexity is introduced by the fact that the plume may move vertically in response to seasonal or artificial (e.g., pumping) changes of one type or another. For these reasons, nested wells are commonly installed to locate the plume and detect vertical movement over time.

Well nests are state-of-the-art for monitoring networks because of the information they can yield. In addition to locating the vertical and areal extent of the plume, head distributions and flow directions can be determined. Generally, the nests should define the bottom of the plume, especially if important aquifers are below the site. This depth may sometimes be inferred from known hydrogeologic data or determined from preliminary borings with water sampling at progressive depths.

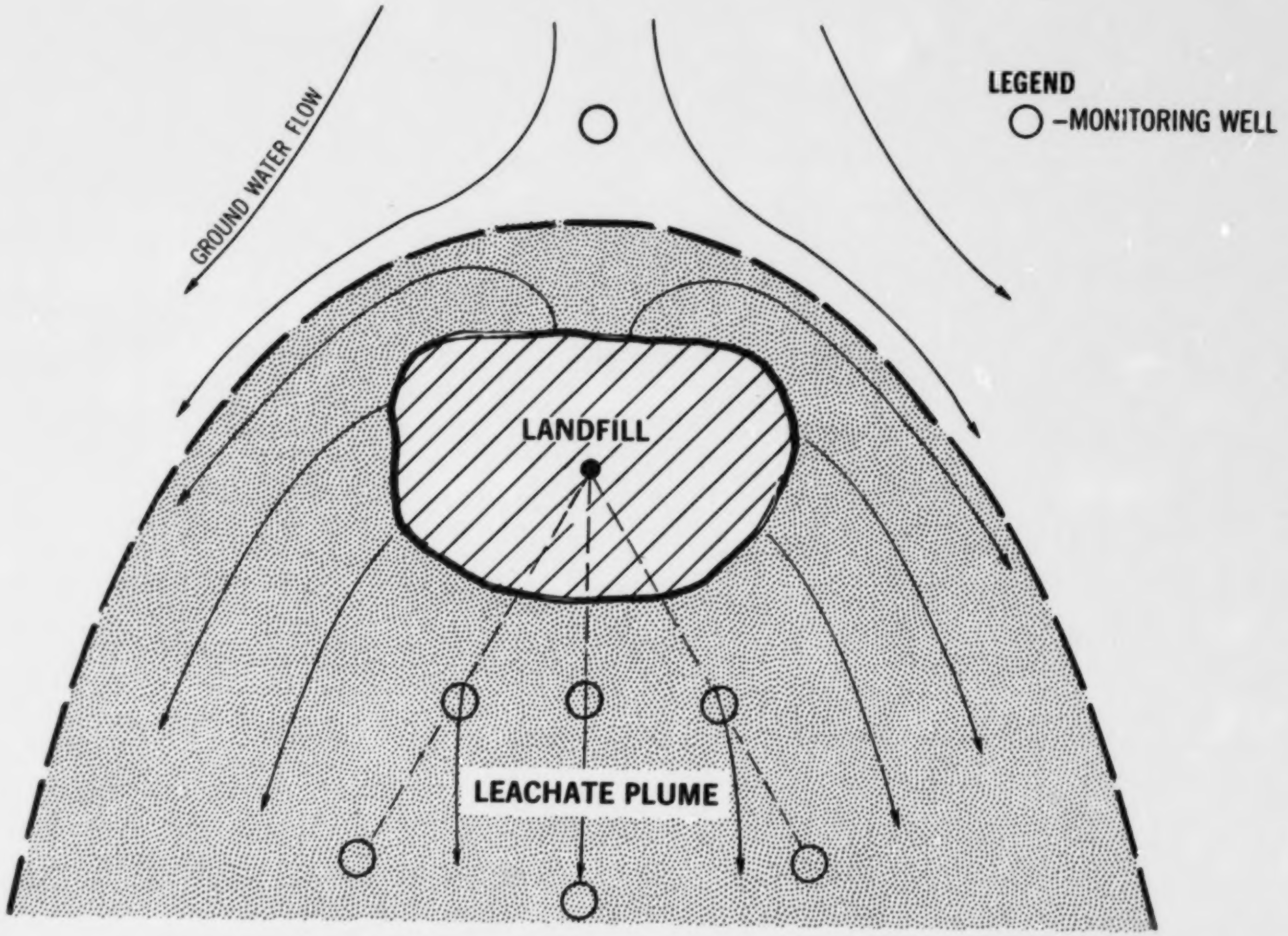
LEGEND
○ -MONITORING WELL
GROUND WATER FLOW
LANDFILL
LEACHATE PLUME

Figure 11. Monitoring Network in an Unconsolidated Aquifer

From Reference 23, Figure 7)

From progressive-depth groundwater sampling, a "snapshot" of the plume's vertical location can be determined. Two of the many procedures for this method in unconsolidated materials include: 1) driving a well point through a hollow-stem auger with sampling at 5 or 10 ft intervals; and 2) collecting aliquots of the air/water/cuttings mixture from a dual-tube reverse-air rotary drilling rig [Appendix D]. Sample analysis is usually limited to several parameters that are indicative of the waste, mobile in the subsurface, and relatively inexpensive to detect (e.g., chloride, sulfate, arsenic, etc.). Based on this initial sampling, the depths of permanent wells are selected so that specific horizons or zones of the plume will be monitored.

DESIGNING THE WELLS

A generally accepted all-inclusive design for monitoring wells is not available; however, many factors are basic to most wells. These common factors make a degree of standardization possible. Many of the engineering design particulars, such as casing and screen material strengths, standard dimensions, weights, and resistance to acid corrosion are covered in considerable detail in other publications and will not be presented here.[4,7,18,40,62] Design factors discussed here are:

Well use
Formation hydraulic characteristics
Screen slot size and length
Casing and screen diameter
Casing and screen materials
Drilling methods [Appendix D]

Although individually discussed, sound practice requires that these factors be considered together. Regardless of individual design, all wells should be fitted with a secure or locking cap to prevent tampering and minimize vandalism.

Well Use

The most fundamental factor in any design is the projected use of the well. If probable uses can be successfully defined and accounted for in the design, the need for costly additional wells may be reduced or eliminated. "Observation wells" are constructed for collecting water samples to locate and track the leachate plume and/or for measuring water levels for determining groundwater flow paths and pressure gradients. "Production-type wells" can also be used for these purposes, but they are designed primarily for conducting tests to estimate aquifer characteristics* and perform remedial measures through injecting purge water or recovering leachate.

In most situations, a well that substantially penetrates an aquifer and is open throughout the saturated thickness is neither required nor desirable. This applies to observation wells installed for monitoring water quality and head levels in certain zones and to production-type wells used for aquifer testing or remedial measures. Consequently, the well screen or bore is designed to be isolated so that only a specific zone is monitored. Sealing materials, such as cement grout and bentonite, are used above the open part of the well to prevent vertical migration of fluids in the annulus between the casing and hole wall. A well with a seal above the monitored zone is called a piezometer.

As a practical matter, in rock wells and those penetrating cohesive, fine-grained, unconsolidated materials, the seal is critical to assure screen or bore isolations. In loose unconsolidated materials where heaving sands are common and/or the borehole collapses immediately upon auger removal, the need for seals below the zone of natural collapse is questionable. Much time, motion, and expense can be wasted in installing seals where they are not reasonably needed.

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* *Wells installed for pump tests generally should not be placed where they would discharge contaminated groundwater because that water would have to be properly disposed of.*

Formation Hydraulic Characteristics

For production-type wells, characteristics such as depth-to-water, permeability, storage coefficients, and the primary way in which water is transmitted (through fractures or around grains) can influence design.

Some networks may be planned so that the formation characteristics are determined during a preliminary drilling phase or initial well set. Formational sampling while drilling should be part of the comprehensive installation plan.

Screen Slot Size and Length

Ideally, for naturally developed wells (those without a gravel pack) screen slot sizes are selected from sieve analysis data for the target horizon or zone in the formation. A plot of grain size vs cumulative percent retained on the sieves is made for study.

For production-type wells, samples for grain-size analysis are normally collected. The samples represent the depth interval to be occupied by the screen. The slot size selected should retain 40% or more of the zone material. In conventional water well design, the percentage range is 40 to 50.[4,40] However, when larger slot sizes are used, more formation material will move into the well during development. If all water removed from the well is to be treated, considerable solids may accumulate in the collection vessel or treatment system, which must also be handled and disposed. In situations where production or injection rates do not require optimum yield, design for the smaller screen openings.

If the required slot size is less than 0.010 in. (10 slot or 60 gauze), a gravel pack should be considered.[40] In gravel-packed wells, the space between the screen and borehole is filled with material coarser than the formation. The principal functions are to:

1. stabilize the formation and minimize pumping of fines,
2. permit use of the largest possible screen slot, and
3. increase the effective well diameter.

Screens should not pass more than 5% of the pack material.[4]

Experience indicates that observation wells are seldom designed with benefit of grain-size analyses from the zone of interest. The usual and recommended procedure is to use a 10-slot screen with or without gravel pack. For most fine-grained unconsolidated formations, such as loess, glacial till, lacustrine, and backwater deposits, the gravel pack is a must. In medium-to-coarse sand or larger materials and in bedrock, a pack is normally not required. For the wide gray area in between, plan to install a gravel pack, but allow flexibility for field evaluation and determination of actual need and practicality.

The process of selecting screen lengths for either a production or observation well is largely subjective. The primary variables are projected well use and purpose and the designer's experience. In most situations, wells will be installed as piezometers to monitor a specific zone or horizon. In these instances, screen lengths rarely exceed 20 ft and are more often 5 to 10 ft. Shorter screens installed in well nests are recommended because they yield more specific information about water quality, head distribution, and flow in the formation. Also, commonly used stainless steel screens become very expensive in longer lengths (more than $300 for a 10 ft x 2 in. screen).

Casing and Screen Diameter

Probably the most important factor in selecting an appropriate well diameter is the size of equipment (pumps, packers, sondes, etc.) the well will have to accommodate. When the depth of water exceeds 25 ft, using electric submersible pumps is desirable for purging and sampling. The smallest commercially available electric submersible pump requires a 3 in. well casing. Submersible pneumatic diaphragm pumps require a 2 in. diameter casing. If the casing is too large, purge volumes (and costs) can be excessive, especially if the purge water must be treated or contained.

Consequently, the 2 and 4 in. diameter casings are the most common for observation and small production wells. As a general rule, if the pumped water level is not expected to fall below 20 ft, 2 in. wells will probably be adequate. For expected pumping levels below 20 ft, use 4 in. or larger casing. The screen and casing diameter are usually the same. Consult references 4 and 40 for more specific information about casing strengths, collapse pressures, etc.

Hybrid well designs with multiple sampling ports or screens have been presented in recent literature due to current interest in groundwater monitoring. Inherent problems with many of these designs include assuring a good seal between the sampling zones (both internal and external), obtaining a sufficient sample in a reasonable length of time, and the relative seriousness of even minor screen plugging (suggested total screen area in one design is less than 0.2 $in.^2$). The relative costs of well design, sample collection, analytical work on water samples and their bearing on remedial measures are ample economic reasons for not cutting too many corners on monitoring wells. Certain situations may clearly justify (either economically or hydrogeologically) installing hybrid wells. However, the recommended approach for most sites is one well/screen per hole, using nests of wells if multiple depth sampling is desirable.

Casing and Screen Materials

Steel and PVC plastic are the most widely used casing and screen materials for monitoring wells at HWSs. Presently, the use of PVC pipe in groundwater contaminated by organic wastes is controversial. The major advantages of PVC pipe are its relatively low cost, light weight, and durability in harsh chemical environments. Opponents claim that the pipe can either absorb/adsorb compounds from the water and render them undetectable or contribute compounds to the water, resulting in an unclear picture of groundwater quality in either case.

Proponents reply that if wells are purged adequately for normal sample collection (3 to 5 casing volumes) and the sample is drawn opposite the screen, any potential interferences would be negligible. Also, if pollutant concentrations are high enough to be of concern, they are unlikely to be substantially removed by sorption to the PVC casing.

Chemical deterioration of PVC casing is possible when either ketones, aromatics, alkyl sulfides, or specific chlorinated hydrocarbons are present. Currently, there is a dearth of information regarding critical concentrations of these solvents where deterioration of the PVC is significant enough to affect sample quality.

If the particular compounds of interest in the groundwater are also components of PVC pipe, its use should definitely be avoided. In contrast, if metals are the pollutants of concern or the groundwater is very acidic, basic, or reactive, steel pipe may not be appropriate and PVC may be the prudent choice; data on contaminants detected which are potentially attributable to the pipe may be of questionable value.

Drilling Methods

Drilling equipment selected for installing monitoring wells must be compatible with the well design and capable of penetrating the geologic materials above the estimated well depth. In general, there are three types of wells based on the installation method:

1. Driven wells
2. Augered wells
3. Drilled wells

Figure 12 shows where these wells types are often installed. Appendix D presents a discussion of well drilling methods and limitations. Dry drilling methods are preferred to avoid introducing extraneous fluids/muds, required in some methods for removing cuttings from the borehole. If drilling fluids are required, the recommended approach is to try

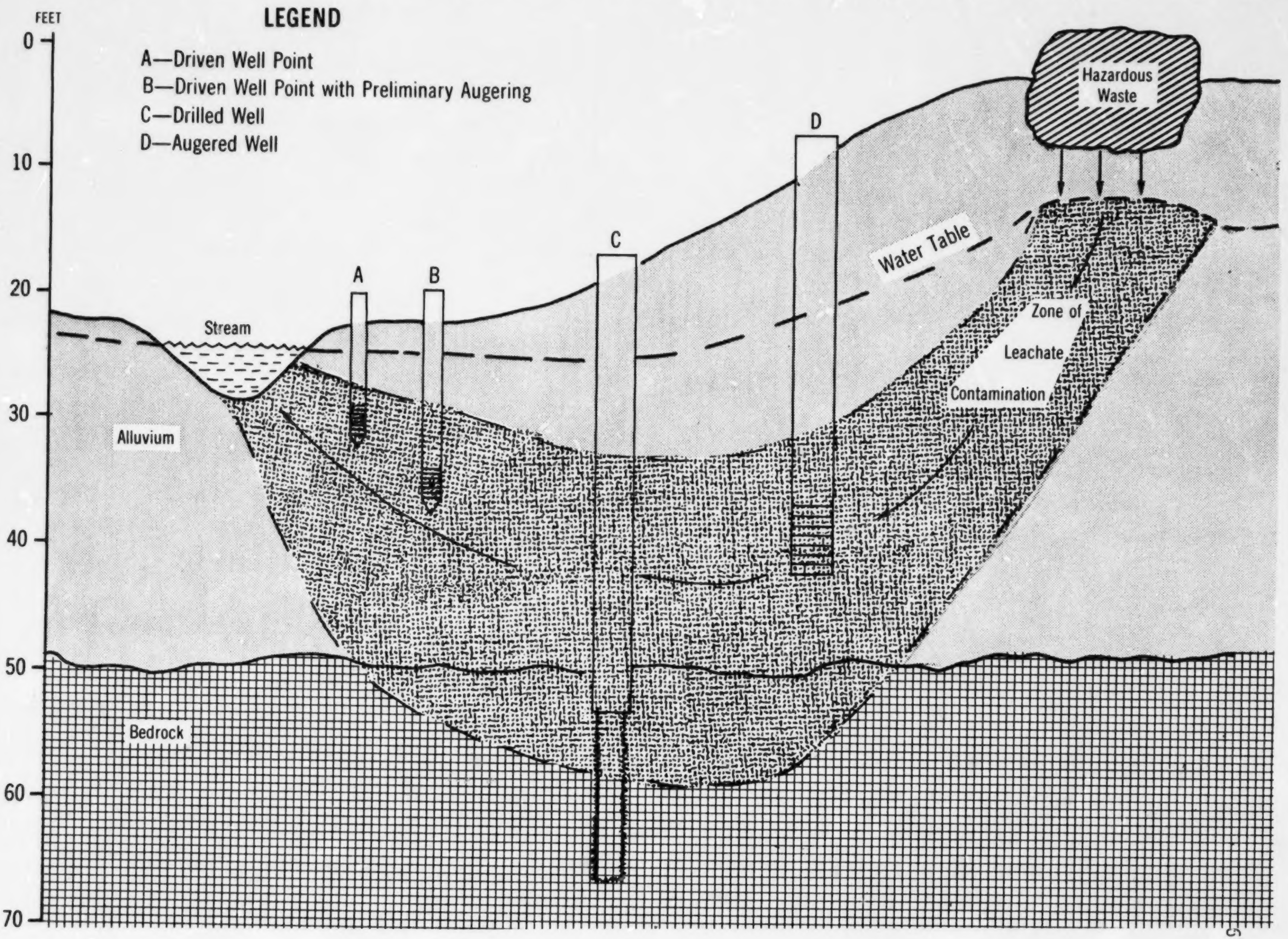
LEGEND
A—Driven Well Point
B—Driven Well Point with Preliminary Augering
C—Drilled Well
D—Augered Well
FEET
0
10
20
30
40
50
60
70
A
B
C
D
Hazardous Waste
Water Table
Zone of Leachate Contamination
Stream
Alluvium
Bedrock

Figure 12. Common Locations of Various Well Types

drinking-quality water without additives first. During one NEIC project, a 300 ft deep well (6" casing) was successfully installed by a contractor in San Joaquin Valley (California) alluvium using only municipal tap water.

INSTALLING THE NETWORK

Several general considerations for installing the monitoring network are discussed here. Installing wells for groundwater pollution investigations is done throughout the country; yet, it cannot be considered truly commonplace anywhere.

Driller Orientation and Technical Overview of Well Construction

Drillers usually contracted for this work normally specialize in either soil exploration or water well drilling. They are unfamiliar with the special health precautions, safety gear, and rig-cleaning procedures required when dealing with hazardous wastes. Time and money should be budgeted for providing any necessary training, fit-testing, etc., to contractor personnel before site work is begun.

When drilling very near or into an HWS, all equipment and procedures should be tested and practiced, respectively, in an uncontaminated offsite location first. Special procedures for drilling safety [Appendix G] should be provided in writing to all involved parties for review and comment. This approach can aid in avoiding costly delays while assuring optimum safety.

Technical overview of well construction should be provided by a full-time, onsite, appropriately trained individual (usually a geologist or engineer) to ensure that the technical requirements of the approved plan of study are met. Also, decisions made while constructing each well frequently require professional attention. At sites where a company consultant and contractor are performing the work, the government's interests are best served by having a trained individual onsite to oversee implementing the plan of study.

Decontaminating Drilling Equipment

During drilling for any groundwater pollution investigation, precautions must be taken to prevent cross-contamination of boreholes. Specifically, the drilling rig and tools should receive a thorough initial cleaning and be cleaned after each borehole. No uniform procedure has been developed for all sites, but a soap wash followed by solvent and distilled water rinse is commonly used. Proper drilling plans can also minimize potential cross-contamination. If possible, drilling should progress from the least to most contaminated areas.

As an example, the following procedure was used for cleaning 3¼ in. inside diameter hollow-stem augers used in silt-size material. Cleaning was done on the bed of a 1½ ton stake body truck, with most equipment rented from a local contractor's supply firm. The principal components were an electric generator, a high-pressure spray washer with a propane-fired water heater, wash and rinse tanks, two 55 gal. drum waste tanks, and an all-metal pump for the acetone drum.

First, an auger was placed horizontally on two cement blocks in an oblong stock-watering tank located at the rear of the truckbed. The high-pressure washer was used to clean the auger with a detergent/water mixture followed by a hot "tap water" rinse. The stock tank drained, by hose, to a 55-gal. drum positioned nearby on the ground. Excess mud in the tank was periodically shoveled into the drum. Next the auger was moved across the truckbed to a rack positioned above a rectangular tub. While in a vertical position, the auger was sprayed with acetone followed by a distilled water rinse, then allowed to air dry. The rectangular tub drained to a separate 55-gal. drum.

Containing and Disposing of Contaminated Materials

Potentially contaminated cuttings and development or purge water must be handled in an environmentally acceptable manner. As of this writing, no formal guidelines or procedures had been established. The basic problem is that the identity, quantity, and concentration of pollutants in these materials are unknown.

If contamination is suspected and the material cannot appropriately be returned to the borehole or applied to the waste fill, the following procedure is recommended. Contain all materials in 55 gal. drums or tanks and store them until samples from the well or boring are chemically analyzed. On the drums, indicate the material contained and borehole number; do not mix wastes from different boreholes as some uncontaminated wastes may end up requiring expensive disposal. When the samples are analyzed, determine proper disposal methods. Slow turnaround times in the laboratory may (and probably will) create storage needs. If onsite storage is not practical, transport the waste to a secure location.*

Sampling During Drilling

Installing monitoring wells should be planned as an intermediate stage in data gathering. A complete drilling program that includes formation sampling, during or preceding well installation, provides a cost effective means of obtaining definitive site specific data on geology and groundwater quality; wells need not be installed at all boring sites.

Both formation and water samples should be collected at progressive depths when searching out a leachate plume. The formation samples are used to define stratigraphy, hydraulic characteristics, and engineering properties (for design of remedial measures). Chemical analyses of formation samples might be performed to study attenuation capabilities, but plume location is better done with water samples because they are easier to analyze and pollutant detection limits are much lower. Also, water is the primary pollutant transport medium.

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* *In instances of severe contamination, appropriate Department of Transportation (DOT) packaging and vehicle placarding may be necessary.*

In bedrock formations, stratigraphy can be defined from either cuttings or core samples and geophysical methods. Core samples, rather than cuttings, are usually required for hydraulic testing.* Commonly, rock cores are collected using a hydraulic rotary rig [Appendix D] and either a conventional or wireline diamond core drill. Wireline coring is usually the preferred method, if available. Water samples can be collected from various horizons in a rock hole using a pump and packer assembly.

For unconsolidated formations, core samples should be used to log stratigraphy and can be used to conduct hydraulic testing. Two general types of core samples can be collected from unconsolidated formations, disturbed and undisturbed. As a practical matter, both core types are disturbed to a greater and lesser extent. The distinction is made here for both the collection method and the types of tests that are properly conducted on each. All disturbed core tests can be run on undisturbed samples [Table 7].

Table 7

APPROPRIATE ANALYSES FOR DISTURBED AND UNDISTURBED CORE SAMPLES[15]

Analysis	Undisturbed	Analysis	Disturbed
Permeability	X	Grain size	X
Unit weight	X	Chemical analysis	X
Consolidation	X	Specific gravity	X
Triaxial compression	X	Water content	X
Unconfined compression	X	Atterberg limits	X
Direct shear	X	Shrinkage limits	X
		Standard compaction	X
		Vibrated density	X

Disturbed samples are usually collected with a thick-walled split-barreled core tube called a split spoon. Although the sample is compressed and somewhat deformed during entry into the core tube, the stratigraphy is easily discernable. Information on relative soil strength, which may be necessary for designing remedial measures, can be obtained during disturbed core collection by the standard penetration test. The test comprises driving a standard 2.0 in. diameter split spoon with a 140 lb hammer freely dropping 30 in.; blow counts are recorded for every 6 in. of penetration. The more blows required, the more resistant the soil is.

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* *If fractures are the primary avenues of groundwater movement in bedrock, hydraulic testing on core samples may provide meaningless data.*

Undisturbed samples are usually collected with a thin-walled core tube (Shelby Tube) with or without a check valve in the upper assembly to improve core retention. Undisturbed core samplers are pushed into the formation with the hydraulic drill head on the rig rather than being driven. Care must be taken during transport to ensure sample integrity. Ideally, the soils laboratory employed would be near the HWS.

There are many variations in soil sampling and analysis techniques. The methods to be employed should be described in the project plan, before drilling begins, and evaluated by a qualified geologist or soil scientist. Detailed information about both disturbed and undisturbed core sampling is contained in references 15 and 82. Sampling programs should also include procedures for cleaning equipment after each sample is collected.

Progressive depth water sampling in unconsolidated materials is addressed in the "Well Placement" section of this chapter and in Appendix D.

Surveying Well Elevations

After the wells are completed each well-head elevation should be established, to third order standards, with respect to a fixed point, the local datum or, preferably, mean sea level.[22] These elevations are as important as water quality to the hydrogeologist because they enable him to determine flow rates and directions, and they can yield much information about designing remedial measures.

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APPENDICES

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APPENDIX A

INFORMATION SOURCES

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5. U.S. DEPARTMENT OF AGRICULTURE
   STATE CONSERVATION OFFICES AND PUBLISHED SOIL SURVEYS
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7. OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) DIRECTORY OF FIELD LOCATIONS
8. MAP PRODUCTS AND SOURCES

PART 1

INFORMATION SOURCES SUMMARY

This part of Appendix A lists a variety of information sources and types potentially useful to HWS investigations. Several sources are keyed to other parts of the Appendix where additional detail is presented. Evidentiary information should be corroborated by several sources, if possible.

SOURCES	TYPES/COMMENTS
1. EPA and State Environmental Office files for: RCRA permits and applications	
Waste Generators and Transporters	EPA Identification numbers Generator annual reports
TOSCA	May require special clearance for reviewer
NPDES permits and applications	Liquid waste types Treatment processes Production information
Uncontrolled waste disposal sites	
Spills of oil and hazardous materials	
Water supplies	Nearest water supply
Enforcement actions	
Surveillance reports	Problem history Previous findings
2. County or Regional Planning Agencies for Areawide Waste Treatment Mgmt. (CWA - Section 208 Agency)	Plans, concerns, and past problems
3. Other County offices	
Health Department	Problems, complaints, analytical results
Planning and zoning	Land use restrictions
Assessor	Plat maps and land owners
4. City offices	
Chamber of Commerce	Information and local industries incl. number of employees, principal products, and facility addresses
Clerk	
Engineer	Foundation and inspection reports Survey benchmark locations
Fire Department	History of fires and/or explosions at facility
Law Enforcement	Complaints and violations of local ordinances

Water and Sewer	Location of buried mains and lines
5. Company files and records	Confidential records require special handling and storage
6. Contractors	
Building	Local soils, geology, and shallow water levels
Soil exploration and foundation Water well drillers	Local soils, geology, hydrogeology, water levels, regulations, and equipment availability
7. Utility Companies Gas Electric Water Petroleum or Natural Gas Pipelines	Location of buried lines
8. U.S. Geological Survey (See Part 2)	Technical geologic and hydrologic reports, maps, aerial photographs, and water monitoring data
9. Remote Sensing Imagery (see Part 3)	Drainage patterns, land use, vegetation stress, historical land development, and geologic structure
10. Computer Data Bases (see Part 4)	Wide variety of reference data and bibliographies
11. U.S. Department of Agriculture (see Part 5)	Soil maps, types, physical characteristics, depths association, and uses
12. State Geological Surveys (see Part 6)	Technical geologic and hydrologic reports, State geologic maps, and monitoring data
13. U.S. Department of Labor Occupational Safety and Health Administration (OSHA) (see Part 7)	Processes Hazards Protective equipment needs
14. National Oceanic and Atmospheric Administration (NOAA)	Climatic data
15. National Ocean Survey Tidal Analysis Branch C232 Rockville, MD 20852 FTS: 443-8311	Tidal data; historic, recent, and projected

PART 2

U. S. GEOLOGICAL SURVEY

Since 1879, the U.S. Geological Survey (USGS) has collected, analyzed, and published detailed information about the Nation's mineral, land, and water resources. Compiled information is available in a variety of map, book, and other formats easily accessed by NEIC personnel. An annually updated "Guide to Obtaining Information from the USGS - Circular 777", is a useful starting point. The Circular may be obtained free of charge from the USGS library at:

Denver West Office Park, Building 3
1526 Cole Boulevard
Golden, Colorado 80401
(FTS) 234-4133

or:

U.S. Geological Survey
704 National Center
Reston, Virginia 22092

The USGS Central Region Headquarters is in Denver, Colorado with many facilities on or near the Denver Federal Center. An information pamphlet on the Central Region's activities and services may be obtained from the map sales office in Building 41. Of primary interest to NEIC personnel conducting HWS investigations are the following:

1. National Cartographic Information Center (NCIC)
    a. Map sales
    b. Aerial photography
2. Reference Library
3. Photographic Library
4. Data Bases for Ground and Surface Water

The USGS map sales office, located on the ground floor of Building 41, offers a wide variety of maps including:

- Topographic quadrangle maps (7½', 15', 1:250,000, etc for all areas west of the Mississippi River including Alaska and Hawaii are kept in stock)
- State base maps
- Metric maps
- Topographic maps of 44 national parks, monuments, and historic sites
- Orthophoto maps
- Land-use maps
- Shaded relief maps
- Slope maps
- Advance copies of maps and special map composites

Acquisition of aerial photographs from NCIC is discussed in Part 3 of this appendix.

The USGS Reference Library, located on the first floor of Building 3 in the Denver West Office Park, is one of four principal USGS publications repositories. The extensive collection is devoted to all aspects of the geosciences including: geology, ground and surface water, soils, and minerals. Many State and U.S. Department of Agriculture publications may also be found there. Lay persons (non-geologists) should have little or no problem locating pertinent geological or water information regarding a study area, provided some exists, in this library.

The USGS Photographic Library, located directly above the Reference Library, contains a special collection of more than 250,000 photographs of subjects taken during geologic studies of the United States, its territories, and foreign countries from 1869 to the present. Most of the photographs are black and white with the more recent being color transparencies. The photographs are indexed by State and county as well as by subject. Copies of the photographs and transparencies may be ordered through the library.

There are three data bases available through the USGS that can yield potentially useful information on ground and surface water:

1. National Water Data Exchange (NAWDEX)
2. National Water Data Storage and Retrieval System (WATSTORE)
3. Catalog of Information on Water Data - Index to Water Data Acquisition

NAWDEX is a computerized data system that can identify USGS (only) sources of water data (i.e., permanent stream stations and monitoring wells) and index the types of data collected from these sources. Actual data from the NAWDEX stations are stored in the WATSTORE computerized data base. Access to these data bases is through the NEIC Technical Information and Analysis Center.

The Catalog of Information on Water Data is an 18-volume series that serves the same purpose as NAWDEX, but includes monitoring stations operated by many other agencies ranging from local to Federal. A complete catalog set is maintained in the NEIC library. Non-USGS data may be available through other data bases (see Part 4 of this appendix) or from the responsible agency.

The USGS Water Resouces Division has district offices in each state, which may supply information on hydrogeologic studies conducted in the area of a HWS under investigation. The following list contains addresses and telephone numbers for the State District Offices.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
State District Offices

University of Alabama
Oil & Gas Bldg - Room 202
P.O. Box V
Tuscaloosa, ALABAMA 35486
FTS-229-2957 205/752-8104

218 E. Street
Anchorage, ALASKA 99501
FTS-399-0150 907/271-4138

Federal Building
301 W. Congress Street
Tucson, ARIZONA 85701
FTS-762-6671 602/792-6671

Federal Office Bldg-Rm 2301
700 West Capitol Avenue
Little Rock, ARKANSAS 72201
FTS-740-6391 501/378-6391

855 Oak Grove Avenue
Menlo Park, CALIFORNIA 94025
FTS-467-2326 415/323-8111

Building 53
Denver Federal Center
Lakewood, COLORADO 80225
FTS-234-5092 303/234-5092

135 High Street - Rm 235
Hartford, CONNECTICUT 06103
FTS-244-2528 203/244-2528

Subdistrict-Dist. Office/MD
Federal Building - Room 1201
Dover, DELAWARE 19901
FTS-487-9128 302/734-2506

325 John Knox Rd-Suite F-240
Tallahassee, FLORIDA 32303
FTS-946-4251 904/386-1118

Suite B
6481 Peach Tree, Indust. Blvd
Doraville, GEORGIA 30360
FTS-242-4858 404/221-4858

Field Headquarters
4398D Loke St. P.O. Box 1856
Lihue, Kauai, GUAM 96766
FTS-245-3252

Subdistrict
U.S. Navy Public Works Ctr
FPO S.F. 96630 - P.O. Box 188
Agana, GUAM 96910

P.O. Box 50166
300 Ala Moana Blvd-Rm 6110
Honolulu, HAWAII 96850
FTS-556-0220 546-8331

P.O. Box 2230
Idaho Falls, IDAHO 83401
FTS-583-2438 208/526-2438

P.O. Box 1026
605 N. Nek Street
Champaign, ILLINOIS 61820
FTS-958-5353 217/398-5353

1819 North Meridan Street
Indianapolis, INDIANA 46202
FTS-331-7101 317/269-7101

Federal Building - Rm 269
P.O. Box 1230
Iowa City, IOWA 52244
FTS-863-6521 319/337-4191

University of Kansas
Campus West
1950 Avenue A
Lawrence, KANSAS 66045
FTS-752-2300 913/864-4321

Federal Building - Room 572
600 Federal Place
Louisville, KENTUCKY 40202
FTS-352-5241 502/582-5241

6554 Florida Boulevard
Baton Rouge, LOUISIANA 70896
FTS-687-0281 504/389-0281

District Office in Mass.
26 Ganneston Drive
Augusta, MAINE 04330
FTS-833-6411 207/623-4797

208 Carroll Building
8600 Lasalle Road
Towson, MARYLAND 21204
FTS-922-3311 301/828-1535

150 Causeway St., Suite 1001
Boston, MASSACHUSETTS 02114
FTS-223-2822 617/223-2822

6520 Mercantile Way - Suite 5
Lansing, MICHIGAN 48910
FTS-374-1561 517/372-1910

702 Post Office Building
St. Paul, MINNESOTA 55101
FTS-725-7841 612/725-7841

Federal Building, Suite 710
100 West Capitol Street
Jackson, MISSISSIPPI 39201
FTS-490-4600 601/969-4600

Mail Stop 200
1400 Independence Road
Rolla, MISSOURI 65401
FTS-277-0824 314/341-0824

Federal Bldg. - Drawer 10076
Helena, MONTANA 59601
FTS-585-5263 406/559-5263

Fed. Bldg/Courthouse-Rm 406
100 Centennial Mall North
Lincoln, NEBRASKA 68508
FTS-541-5082 402/471-5082

Federal Building - Room 227
705 North Plaza Street
Carson City, NEVADA 89701
FTS-470-5911 702/882-1388

Subdistrict-Dist.Off./Mass
Federal Bldg - 210
55 Pleasant Street
Concord, NEW HAMPSHIRE 03301
FTS-834-4739 603/224-7273

Federal Bldg. Rm 436
402 E. State St-P.O. Box 1238
Trenton, NEW JERSEY 08607
FTS-483-2162 609/989-2162

Western Bank Building
505 Marquette, NW
Albuquerque, NEW MEXICO 87125
FTS-474-2430 505/766-2430

236 US Post Office/Crthouse
P.O. Box 1350
Albany, NEW YORK 12201
FTS-562-3107 518/472-3107

Century Station - Room 436
Post Office Building
P.O. Box 2857
Raleigh, NORTH CAROLINA 27602
FTS-672-4510 919/755-4510

821 E. Interstate Avenue
Bismarck, NORTH DAKOTA 58501
FTS-783-4601 701/255-4011

975 West Third Avenue
Columbus, OHIO 43212
FTS-943-5553 614/469-5553

215 NW 3rd - Room 621
Oklahoma Cty, OKLAHOMA 73102
FTS-736-4256 405/231-4256

(Mail) P.O. Box 3202
Ship-830 NE Holladay St, 97232
Portland, OREGON 97208
FTS-429-5242 503/231-5242

Federal Bldg - 4th Floor
P.O. Box 1107
Harrisburg, PENNSYLVANIA 17108
FTS-590-4514 717/782-4514

Building 652, Ft. Buchanan
G.P.O Box 4424
San Juan, PUERTO RICO 00936
FTS-967-1221 809/783-4660

District Office in Mass.
Federal Bldg & U.S. P. O.
Room 224
Providence, RHODE ISLAND 02903
FTS-838-4655 401/528-4655

Strom Thurmond Federal Bldg.
1835 Assembly St. - Suite 658
Columbia, SOUTH CAROLINA 29201
FTS-677-5966 803/765-5966

Federal Bldg. - Room 308
200 4th St., S.W.
Huron, SOUTH DAKOTA 57350
FTS-782-2258 605/352-8651

U.S. Courthouse
U.S. Federal Building-A-413
Nashville, TENNESSEE 37203
FTS-852-5424 615/251-5424

Federal Building - 649
300 East 8th Street
Austin, TEXAS 78701
FTS-734-5766 512/397-5766

Administration Bldg - 1016
1745 West 1700 South
Salt Lake, UTAH 84104
FTS-588-5663 801/524-5663

District Office in Mass.
US Post Office/Courthouse
Rooms 330B and 330C
Montpelier, VERMONT 05602
FTS-832-4479 802/229-4500

200 West Grace St - Rm 304
Richmond, VIRGINIA 23220
FTS-925-2427 804/771-2427

1201 Pacific Ave - Suite 600
Tacoma, WASHINGTON 98402
FTS-390-6510 206/593-6510

Fed. Building/US Courthouse
500 Quarrier St, East-Rm 3017
Charleston, WEST VIRGINIA 25301
FTS-924-1300 304/343-6181

1815 University Building
Madison, WISCONSIN 53706
FTS-262-2488 608/262-2488

P.O. Box 1125
J.C. O'Mahoney Federal Ctr
2120 Capitol Ave. - Rm 5017
Cheyenne, WYOMING 82001
FTS-328-2153 307/778-2220

PART 3

OBTAINING AERIAL PHOTOGRAPHS

AERIAL PHOTOGRAPH USES

Aerial photographs are an effective and economical tool for gathering information on HWSs. They provide a perspective not afforded by topographic maps, especially when the site has not been visited previously. Available photographs are usually black and white, but can include color, near infrared, infrared, and multispectral scanner imagery. These pictures may have been taken from conventional aircraft, Skylab, or a satellite (LANDSAT).

Potential photograph uses are determined before requesting either existing imagery or a site overflight. A black and white photograph with a scale of 1:24,000 can clearly show the disposal site and area drainage. It may also be used to develop a base map for the study area. Special overlapping photographs (stereo pairs) can be viewed with a "stereoscope" to produce a three-dimensional image of the land surface. Geologic, hydrologic, and land form features, previously discussed, can often be identified by this technique. A series of historical photographs may be used to trace site development over time.

Near infrared photographs are used to depict stressed and unstressed vegetation, plant densities, and identifications. Infrared images show relative temperatures and heat loss. For example, cool groundwater springs might be detected flowing down a relatively warm hillside near the disposal site. Finally, multispectral scanner images from satellites may be useful for special applications or where the study area is large. Data needs should be discussed with the staff photo interpreter (P.I.).

Interpretation should be performed by qualified personnel for both legal and practical reasons. In most cases, the trained P.I. can evaluate aerial photographs more completely and accurately than others. Conclusions drawn from photographs are verified (ground truth) during the site inspection.

SOURCES OF AVAILABLE PHOTOGRAPHS

Information on and sources of aerial photographs and other imagery include:

1. Technical Analysis Branch (TAB), NEIC
2. Rocky Mountain National Cartographic Information Center (NCIC)
   U.S. Geological Survey
   Building 25, Denver Federal Center, Room H-2206
   Denver, Colorado 80225
   (FTS) 234-2326
3. Environmental Photographic Interpretation Center (EPIC)
   P.O. Box 1587
   Vint Hill Farm Station
   Warrenton, Virginia 22186
   (FTS) 557-3110
4. Environmental Monitoring Systems Laboratory (EMSL)
   P.O. Box 15027
   Las Vegas, Nevada 89114
   (FTS) 595-2969

TAB personnel can research available resources for archival imagery and/or arrange for collection of new imagery. In-house imagery from previous NEIC surveys is maintained by TAB and is indexed in an internal August 12, 1980 document titled "Computer Data Base of Aerial Reconnaissance Film."

The NCIC office on the second floor of Building 25 has imagery for the U.S. on cassette reels that are available for viewing on request. The center also maintains a computerized inquiry and ordering service for Landsat, NASA, Skylab, and aerial mapping photography. Order photographs as soon as your need is known because one-to-three weeks are required for delivery.

EPIC has access to the same imagery provided by NCIC and some that is classified by the Department of Defense. This group is able to provide more sophisticated imagery interpretation and special mapping than is generally available in-house at NEIC.

EMSL is capable of flying both simple and sophisticated remote sensing missions. Their equipment ranges from mapping quality black and white or color cameras to multispectral scanners with a variety of airborne sensor platforms. Generally, they can provide full remote sensing services to governmental organizations.

All requests for imagery should be coordinated by TAB personnel due to the Dow vs EPA case, which is yet to be resolved.

AERIAL RECONNAISSANCE TECHNIQUES

There are five basic types of aerial reconnaissance techniques:

Light Aircraft

1. Observer only
2. Hand-held cameras
3. Enviro-pod

Reconnaissance Aircraft

4. Standard Aerial Photography
5. Special Remote Sensing Techniques

The simplest techniques use a light aircraft, available for charter at many general aviation airports. If photographs for permanent records are not needed, the aerial reconnaissance can be made by the inspector flying as an observer. In most cases, however, photographs will be desirable. These can be obtained economically by hand-held cameras. For small sites, the inspector can usually serve as observer and photographer. For complex sites two people are recommended, one serving as an observer and recorder and the other as photographer. All photographs and visual observations should be documented in a bound log book.

By making repeated passes over a site from different directions and at different altitudes, it is possible to obtain a wide variety of photographs with hand-held cameras. In general, these will be oblique (on a slant) photographs, although nearly vertical photographs are possible. Oblique photographs are very useful in showing overall details of a site, as well as small details of specific facilities such as stacks of drums, spills, tanks, and treatment units. A disadvantage of hand-held photographs is that it is nearly impossible to produce photographs with uniform scale across the image so they can be used for mapping. Vertical mapping cameras are necessary to produce uniform scale images.

The simplest technique for obtaining high quality photographs is the Enviro-Pod. This is a capsule containing two 70 mm cameras that can be attached to the underside of a light aircraft. One camera takes vertical photographs and the other, forward oblique photographs. The unit, which is portable, can be transported by airlines as baggage, produces high quality photographs at a cost only slightly higher than the hand-held camera. A disadvantage is that the Enviro-Pod is currently only certified for attachment to Cessna models 172 and 182 aircraft.

The best quality mapping photographs are produced by standard aerial photography procedures, using specially equipped reconnaissance aircraft with vertically mounted cameras. This technique produces most of the aerial photographs used by surveying and mapping firms, for production of topographic maps, and by various government agencies. Most large metropolitan areas have commercial aerial photography services available.

Generally, aerial mapping color photographs are originally in the form of positive transparencies (a 35 mm slide is a positive transparency). They are in rolls that may vary in width from 70 mm to 9 inches. Mapping cameras can record overlapping photographs, which allows stereo viewing. Good film resolution provides acceptable detail on prints as large as 16 to 20 inches. Since the scale is nearly uniform across the print, the print can be used for site mapping.

Note: Until final resolution of the Dow vs EPA case, EPA investigators and contractor personnel must consult the EPA Regional Enforcement Director prior to initiation of aerial imagery projects.

PART 4

SELECTED DATA BASES
FOR
HAZARDOUS WASTE SITE INVESTIGATIONS

SELECTED DATA BASES FOR HAZARDOUS WASTE SITE INVESTIGATIONS
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
DENVER, COLORADO

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
AEROS	Aerometric and Emissions Reporting System (AEROS) is a management information system for EPA's air pollution research and control programs. Eleven retrieval systems are sub-systems of AEROS system: 1. National Emissions Data System (NEDS) - Source and emissions-related data for the five criteria pollutants. 2. Storage and Retrieval of Aerometric Data (SAROAD) System - Information relating to ambient air quality. 3. Hazardous and Trace Substance Emissions System (HATREMS) - Sources and emissions data for non-criteria pollutants. 4. Source Test Data (SOTDAT) System - Technical data collected during source emissions measurements (i.e., stack tests). 5. State Implementation Plans (SIPS) regulation system - EPA-approved state air pollution control regulations. 6. Emissions History Information System - Historical trends information on nationwide emissions. 7. Air Pollutant Emissions Report (APER) tracking system - Records of APER forms mailed to emissions sources required to report data to EPA. 8. Weighted Sensitivity Analysis Program (WSAP)-Computes error which can be tolerated in the emission estimate for each source category. 9. Source Inventory and Emission Factor Analysis (SIEFA) Program - Complements WSAP; computes actual error in emission estimates for each source category. 10. Computer Assisted Area Source emissions (CAASE) Gridding System - Performs calculations to apportion NEDS county emissions totals to subcounty gridded areas. 11. Regional Emissions Projection System (REPS) - Makes regional emission projections up to the year 2000.			EPA Research Triangle Park	

SELECTED DATA BASES FOR HAZARDOUS WASTE SITE INVESTIGATIONS (Cont.)

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
AGRICOLA	Covers worldwide journal and monographic literature in agriculture and related subject fields, including general agriculture and rural sociology; animal science; forestry and plant-related areas; entomology; and agricultural engineering. Includes agriculture Canada.	1970-Pres.	Over 1 million citations. Monthly updates	U.S.National Agricultural Library	Citations only
APTIC	Covers most sources for citations concerning all aspects of air pollution, its effects, prevention and control.	1966-Oct. 1978	89,000 citations	Manpower and Technical Information Branch EPA.	Abstracts
ASI	American Statistics Index covers statistical publications containing the entire spectrum of social economic and demographic data collected and analyzed by all branches and agencies of the U.S. government.	1973-Pres. (some material from 1960's).	Over 55,000 citations, monthly updates	Congressional Information Service, Inc.	Abstracts
BIOSIS PREVIEWS	Covers all aspects of the life sciences, drawing upon all original published literature for citations. Corresponds to Biological Abstracts and Biological Abstracts/RRM.	1969-Pres.	2,265,000 records; Monthly updates	Information Service	Biosciences only
CA CONDENSATES '70-71	Covers all aspects of the chemical literature both applied and theoretical. Corresponds to Chemical Abstracts.	1970-1971	585,000 records	Chemical Abstracts Service	Citations only
CA CONDENSATES/ CASIA	Gives general subject index headings and CAS registry numbers for documents covered by CA condensates.	1972-Pres.	Corresponds to CA Condensates after initial file load. Biweekly updates.	Chemical Abstracts Services	Description and identifiers only
CAB ABSTRACTS	Comprehensive file of agricultural information pertaining to all significant material and covering every aspect of crop and animal science.	1973-Pres.	Over 966,000 items. Monthly updates	The Commonwealth Agricultural Bureau	Abstracts
CANCERLIT	(Formerly Cancerline). Contains information on various aspects of cancer taken from over 3,000 U.S. and foreign journals as well as selected monographs, papers, reports and dissertations.	1963-Pres.	Over 100,000 Abstracts of Articles; Updated monthly	National Cancer	Abstracts
CHEMDEX	Chemdex is based on the CA Registry Nomenclature File, which is a respository for names associated with substances that have been registered by Chemical Abstracts. In addition to CA's rigorous nomenclature data, this file contains registry numbers, molecular formulas, synonyms and ring system information.	Contains all substances cited in the CA Abstracts volumes since 1972.	694,461 substances; quarterly updates	Chemical Abstracts Service of the American Chemical Society	
CHEMLINE	Chemline is an online chemical dictionary file providing a mechanism for searching and retrieving chemical substance names. It contains 439,812 records for chemicals that are identified by chemical abstracts service registry numbers and are cited in either Toxline, Toxback, TDB, or RTECS.		Irregular updates	National Library of Medicine	

SELECTED DATA BASES FOR HAZARDOUS WASTE SITE INVESTIGATIONS (Cont.)

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
CHEMNAME	Contains CAS registry numbers, CA substance index names, molecular formulas, chemical name synonyms and periodic classification terms for chemical substances.	Corresponds to CASIA	737,000 substances; quarterly updates	Chemical Abstracts Service and Lockheed	Gives names and CAS registry numbers only
CLAIMS/CHEM	U.S. chemical and chemically-related patents plus some foreign equivalents.	1950-1970	265,000 citations	IFI/Plenum Data Co.	Citations
COMPREHENSIVE DISSERTATION ABSTRACTS	Interdisciplinary listing of almost all doctoral dissertations accepted since 1861 by accredited degree granting institutions in the U.S. plus some non-U.S. universities.	1861-Pres.	Over 648,000 citation. monthly updates	Xerox University Microfilms	Citations only
CONFERENCE PAPERS INDEX	Covers approximately 1,000 scientific and technical meetings worldwide and the 100,000 papers presented.	1973-Pres.	715,000 records monthly updates	Data Courier	
EDB	The energy data base covers all information of interest to DOE in almost every area of research.	1974-Pres. (Contains material back to late 1800's	98,700 citations. 5,000 items semimonthly	DOE Technical Information Center	Abstracts (after June 1, 1976)
EIS INDUSTRIAL PLANTS	Information on 130,000 establishments operated by 67,000 firms with current annual sales of over $500,000 describing employment, sales, market share and production.	Current	140,000 records; replaced 3 times/year	Economic Information Systems	Citations only
EMI (EMIC)	Environmental mutagens - information concerning chemical mutagen research.	1976-Pres.		DOE-TIC	Abstracts
ENVIRONMENTAL PERIODICALS BIBLIOGRAPHY (EPB)	Covers the very broad field of general human ecology, atmospheric studies, energy, land resources, water resources and nutrition and health from 300 periodicals.	1973-Pres.	Over 158,000 records. Bimonthly updates	Environmental Studies Institute	Citations
EXCERPTA MEDICA	Covers all fields of medicine plus extensive coverage of the drug and pharmaceutical literature and other areas such as environmental health and pollution control.	June 1974-Pres.	1,160,000 records, monthly updates	Excerpta Medica	Abstracts
FEDERAL INDEX	Substantive comments from the Congressional Record, Federal Register, Presidential documents, and the Washington Post. Trends and developments in Washington are provided by citations to the Code of Federal Regulations, the US Code, public laws, congressional bills, and resolutions and reports. Coverage extends to proposed rules, regulations, bill introductions, speeches, hearings, roll calls, reports, vetoes, court decisions, executive orders, contract awards, etc.	Oct. 1976-Pres.	130,000 citations, monthly updates	Predicasts	Citations only
FEDERAL REGISTER	Contents correspond to the Federal Register Abstracts.	March 1977-Pres.	Weekly	Capitol Services	Citations

SELECTED DATA BASES FOR HAZARDOUS WASTE SITE INVESTIGATIONS (Cont.)

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
GEOARCHIVE	Covers geoscience information. Mineral and petroleum production and resources and new names typify the data currently added to the fields of geophysics, geochemistry, geology, paleontology and mathematical geology.	1969-Pres.	290,000 citations; monthly updates	Geosystems of London	Abstracts
GEOREF	Covers geosciences literature from 3,000 journals, plus the geosciences conferences and major symposia and monographs in all areas of the geosciences.	1961-Pres.	360,000 items; 4,000 records/month	American Geological Institute	Citations
IPA	Information on all phases of development and use of	1970-Pres.	43,000 items 500-600 added monthly	American Society of Hospital Pharmacists	
MEDLINE	Bibliographic citations to worldwide medical literature corresponds to Index Medicus.	1976-Pres.	Over 815,000 citations	National Library of Medicine	Abstracts when available
MGA	Covers meteorological and geoastrophysical research published in both foreign and domestic literature. Based on Meteorological and Geoastrophysical Abstracts.	1970-Pres.	43,500 citations, irregular updates	American Meteorological Society	Abstracts
NAWDEX	National Water Data Exchange - Contains information concerning water data availability, source and some major data characteristics.	1700's - Pres	As necessary data from 61,500 sites stored.	U.S. Geological Survey	
NBI	National Biomonitoring Inventory - Information on on-going biomonitoring projects in the U.S.	Current	As necessary	DOE-TIC	Abstracts
NCC	National Climatic Center - Contains historical and current weather information and related data. The data is generated by: NOAA's Weather Service; the U.S. Navy and U.S. Air Force weather services; the Federal aviation Administration; the U.S. Coast Guard; and cooperative observers.	1800's -Pres.	Continuous	National Oceanic and Atmospheric Admin.	
NRC	The National Referral Center file is non-bibliographic file containing descriptions of organizations qualified and willing to answer questions on virtually any area of science and technology, including the social sciences.	Current		National Referral Center for Science & Technology	Citations only
NSA	Nuclear Science Abstracts - Subject scope includes all of nuclear science and technology.	1967-1976	554,597 records; closed	DOE-TIC	Abstracts
NSC	Covers all pertinent literature on nuclear safety information.	1963-Pres.	101,340 items; 1,000 citations per month	Nuclear Safety Information Center, Oak Ridge National Laboratory	Abstracts

SELECTED DATA BASES FOR HAZARDOUS WASTE SITE INVESTIGATIONS (Cont.)

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
NSR	The Nuclear Structure Reference data base contains: 1. The entire contents of "Nuclear Structure References, 1969-1974," supplement to Vol. 16, Nuclear Data Sheets. 2. Complete contents of the 1975 "Recent References" issues of Nuclear Data Sheets; and 3. References to reports and informal communications (secondary sources) received by the nuclear data project during the years 1973-1975.	1974-Pres. 5,000 entries	30,236 items; 5,000 entries per year	Oak Ridge National Laboratory	Citations only
NTIS	Complete government reports announcement file. Contains abstracts of research reports from over 240 government agencies including NASA, EPA, HEW, etc.	1964-Pres.	765,000 citations; biweekly updates	National Technical Information Service	Abstracts
OHM-TADS	Oil and Hazardous Materials-Technical Assistance Data System contains data on materials that have been designated oil or hazardous materials. The system is designed to provide technical support for dealing with potential or actual dangers resulting from the discharge of oil or hazardous substances.	Oct. 1978-Pres.		EPA-Oil & Special Materials Control Division	
PARCS	Pesticides Analysis Retrieval and Control System (PARCS) provides a centralized source of information on all pesticides registered by EPA.			EPA	
POLLUTION ABSTRACTS	Corresponds in coverage to the printed abstracts publication. Covers foreign and domestic reports, journals, contracts and patents, symposia, and government documents in the areas of pollution control and research: water, marine, land and thermal pollution; pesticides; sewage and waste treatments; and legal developments.	1970-Pres.	68,500 citations; bimonthly updates	Data Courier, Inc.	Citations only
RASS	Rock analysis Storage System - Contains information on samples submitted for analytical work. Information includes location, formation, sample name, age, description, economic geology, data, and geochemical data.	1962 - Pres. 1968 - Pres. (2 files)	As necessary 135,000 records 292,000 records	U.S. Geological	
RING DOC	RINGDOC covers over 400 of the world's scientific journals to provide extensive coverage of the pharmaceutical literature. Access points to the citations include keywords and multipunch coded data (representing chemical fragments).	1964-Pres.	466,000 items 10,000 items/month	Derwent Publications, Ltd.	Available to subscribers only
RTECS	Registry of Toxic Effects of Chemical Substances.	1978	40,967 records	NIOSH	

SELECTED DATA BASES FOR HAZARDOUS WASTE SITE INVESTIGATIONS (Cont.)

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
SAFETY	Safety provides international coverage of the literature in 6 major areas: general safety, industrial and occupational safety, transportation safety, aviation and aerospace safety, environmental and ecological safety, and medical safety.	June 1975-Pres.	Updated bi-monthly	Cambridge Scientific Abstracts, Riverdale, MD	Abstracts
SCISEARCH	Multidisciplinary index to the literature of science and technology. Based on Science Citation Index which indexes approximately 2,600 major scientific and technical journals.	1974-Pres.	2,970,000 citations; monthly updates	Institute for Scientific Information	Citations only
STORET	Storage and retrieval of water quality data - repository for water quality data that contains records of water quality parametric data by sampling site.	1976-Pres.	Bi-monthly	Paint Research	Abstract
TOXICOLOGY DATA BANK (TDB)	Contains facts and data from some 80 standard references textbooks, handbooks, monographs, and criteria documents, for approximately 2500 substances; 1100 of these have been completed; 1500 are in process. TDB contains approximate 60 different categories of data, such as chemical, physical, biological, pharmacological, toxicological, and environmental facts.	1978-Pres	2500 Substances	National Library of Medicine	
TOXLINE	Contains data on toxicity and adverse effects of environmental pollutants and chemicals on the human food chain, laboratory animals, and biological systems; and analysis techniques in the following subfiles: CBAC - 1965-76 - Chemical abstracts, biochemistry sections. EMIC - 1971-74 - Environmental Mutagen Information Center. ETIC - 1950 - Environmental Teratology HAYES - 1970 - EPA Pesticide File HEEP - 1971-76 - Health Effects of Environmental Pollutants IPA - 1970-76 - International Pharmaceutical Abstracts PESTAB - (Formerly HAPAB) - 1966-76 - Pesticide Abstracts, EPA TERA - 1971-1974 - Teratology TMIC - 1971 - Toxic Materials Information Center TOXBIB - 1968-76 - Index Medicus Toxicity Subset	Varies with subject file	Varies with subject file. 479,926 records	National Library of Medicine	Citations; (Abstracts available)
WATSTORE	Water Data Storage and Retrieval System - Contains data on the occurrence, quantity, quality, distribution, and movement of surface and underground waters.	Historical - Pres.	As necessary. Includes data on over 100,000 sites	U.S. Geological Survey	

DATA BASE STATUS FOR JANUARY 1981 (Cont.)

Data Base Name	Subject Coverage	Coverage Dates	Update Frequency	Sponsoring Agency	Comments
WESTLAW	Contains Supreme Court full text and headnote summaries from 1932 - present; headnote summaries for all reported Federal court cases from 1960 - present; and all reported State Appellate Court cases from 1967 - present. Full test accessible for all Federal court cases in the data data base and Appellate Court cases from 1977 - present. The subfiles correspond to the units of the West Company National Reporter System.	1932-pres.	Number of items varies with subject files	West Publishing Company	
WRA	Corresponds to the semi-monthly abstracting journal, Selected Water Resources Abstracts. Covers the water-related aspects of the life, physical, and social sciences as well as related engineering and legal aspects of the characteristics, conservation, control, use or management of water. Input material for the abstracts comes from selected organizations with active water resources research programs which are supported as "Centers of Competence."	1969-Pres.	94,610 items 1,000 items/mon.	Water Resources Scientific Information Center	Abstracts

PART 5

U.S. DEPARTMENT OF AGRICULTURE

STATE CONSERVATION OFFICES
AND
PUBLISHED SOIL SURVEYS

STATE CONSERVATION OFFICES

ALABAMA, Auburn 36830
Wright Building
138 South Gay Street
P.O. Bo 311
Phone: 534-4535 (FTS)
205-821-8070 (CML)

ALASKA, Anchorage 99504
Suite 129, Professional Bldg.
2221 E. Northern Lights Blvd.
Phone: 907-276-4246 (FTS & CML)[a]

ARIZONA, Phoenix 85025
230 N. 1st Avenue
3008 Federal Building
Phone: 602-261-6711 (FTS & CML)

ARKANSAS, Little Rock 72203
Federal Building, Room 5029
700 West Capitol Street
P.O. Box 2323
Phone: 740-5445 (FTS)
501-378-5445 (CML)

CALIFORNIA, Davis 95616
2828 Chiles Road
Phone: 916-758-2200 ext. 210
(FTS & CML)

COLORADO, Denver 80217
2490 W. 26th Avenue
P.O. Box 17107
Phone: 327-4275 (FTS)
303-837-4275 (CML)

CONNECTICUT, Storrs 06268
Mansfield Professional Park
Route 44A
Phone: 244-2547/2548 (FTS)
203-429-9361/9362 (CML)

DELAWARE, Dover 19901
Treadway Towers, Suite 2-4
9 East Loockerman Street
Phone: 487-5148 (FTS)
302-678-0750 (CML)

FLORIDA, Gainesville 32602
Federal Building
P.O. Box 1208
Phone: 946-3871 ext. 100 (FTS)
904-377-8732 (CML)

GEORGIA, Athens 30603
Federal Building
355 E. Hancock Avenue
P.O. Box 832
Phone: 250-2275 (FTS)
404-546-2274 (CML)

HAWAII, Honolulu 96850
300 Ala Moana Blvd.
Room 4316
P.O. Box 5004
Phone: 808-546-3165 (FTS & (CML)[b]

IDAHO, Boise 83702
304 North 8th Street, Room 345
Phone: 554-1601 (FTS)
208-384-1601 ext 1601 (CML)

ILLINOIS, Champaign 61820
Federal Building
200 W. Church Street
P.O. Box 678
Phone: 958-5271 (FTS)
217-356-3785 (CML)

INDIANA, Indianapolis 46224
Atkinson Square-West Suite 2200
5610 Crawfordsville Road
Phone: 331-6515 (FTS)
317-269-3785 (CML)

IOWA, Des Moines 50309
693 Federal Building
210 Walnut Street
Phone: 515-862-4260 (FTS & CML)

KANSAS, Salina 67401
760 South Broadway
P.O. Box 600
Phone: 752-4753 (FTS)
913-825-9535 (CML)

KENTUCKY, Lexington 40504
333 Waller Avenue
Phone: 355-2749 (FTS)
606-233-2749 ext 2749 (CML)

LOUISIANA, Alexandria 71301
3737 Government Street
P.O. Box 1630
Phone: 497-6611 ext 233 (FTS)
318-448-3421 (CML)

MAINE, Orona 04473
USDA Building
University of Maine
Phone: 833-7393 (FTS)
207-866-2132/2133 (CML)

MARYLAND, College Park 20740
Room 522, Hartwick Building
4321 Hartwick Road
Phone: 301-344-4180 (FTS & CML)

MASSACHUSETTS, Amherst 01002
29 Cottage Street
Phone: 413-549-0650 (FTS & CML)[c]

MICHIGAN, East Lansing 48823
1405 South Harrison Road
Room 101
Phone: 374-4242 (FTS)
517-372-1910 ext 242 (CML)

MINNESOTA, St. Paul 55101
200 Federal Bldg & U.S. Courthouse
316 North Robert Street
Phone: 612-725-7675 (FTS & CML)

MISSISSIPPI, Jackson 39205
Milner Building, Room 590
210 South Lamar Street
P.O. Box 610
Phone: 490-4335 (FTS)
601-969-4330 (CML)

MISSOURI, Columbia 65201
555 Vandiver Drive
Phone: 276-3145 (FTS)
314-442-2271 ext 3155 (CML)

MONTANA, Bozeman 59715
Federal Building
P.O. Box 970
Phone: 585-4322 (FTS)
406-587-5271 ext 4322 (CML)

NEBRASKA, Lincoln 68508
Federal Building
U.S. Courthouse, Room 345
Phone: 541-5300 (FTS)
402-471-5301 (CML)

NEVADA, Reno 89505
U.S. Post Office Bldg. Rm 308
P.O. Box 4850
Phone: 470-5304 (FTS)
702-784-5304 CML)

NEW HAMPSHIRE, Durham 03824
Federal Building
Phone: 834-0505 (FTS)
603-868-7581 (CML)

NEW JERSEY, Somerset 08873
1370 Hamilton Street
P.O. Box 219
Phone: 342-5341
201-246-1205 ext 20 (CML)

NEW MEXICO, Albuquerque 87103
517 Gold Avenue, SW
P.O. Box 2007
Phone: 474-2173 (FTS)
505-766-2173 (CML)

NEW YORK, Syracuse 13260
U.S. Courthouse & Federal Bldg.
100 S. Clinton Street, Room 771
Phone: 950-5494 (FTS)
315-423-5493 (CML)

NORTH CAROLINA, Raleigh 27611
310 New Bern Ave, Federal Bldg
Room 544 P.O. Box 27307
Phone: 672-4210 (FTS)
919-755-4165 (CML)

NORTH DAKOTA, Bismarck 58501
Federal Bldg. - Rosser Ave & 3rd St.
P.O. Box 1458
Phone: 783-4421 (FTS)
701-255-4011 ext 421 (CML)

OHIO, Columbus 43215
200 No. High St, Room 522
Phone: 943-6962 (FTS)
614-469-6785 (CML)

OKLAHOMA, Stillwater 74074
Agriculture Building
Farm Road & Brumley Street
Phone: 728-4360 (FTS)
405-624-4360 (CML)

OREGON, Portland 97209
Federal Office Building
1220 SW 3rd Avenue
Phone: 423-2751 (FTS)
503-221-2751 (CML)

STATE CONSERVATION OFFICES (Cont.)

PENNSYLVANIA, Harrisburg 17108
Federal Bldg. & Courthouse
Box 985 Federal Square Station
Phone: 590-2202 (FTS)
717-782-4403 (CML)

PUERTO RICO, Hato Rey 00918
Federal Office Bldg. Room 633
Mail: GPO Box 4868
PUERTO RICO, San Juan 00936
Phone: 809-753-4206[d]

RHODE ISLAND, West Warwick 02893
46 Quaker Lane
Phone: 401-828-1300 (FTS)[e]

SOUTH CAROLINA, Columbia 29210
240 Stoneridge Drive
Phone: 677-5681 (FTS)
803-765-5681 (CML)

SOUTH DAKOTA, Huron 57350
Federal Bldg 200 4th St, SW
P.O. Box 1357
Phone: 782-2333 (FTS)
605-352-8651 (CML)

TENNESSEE, Nashville 37203
675 U.S. Courthouse
Phone: 852-5471 (FTS)
615-749-5471 (CML)

TEXAS, Temple 76501
W.R. Poage Federal Building
101 S. Main St. P.O. Box 648
Phone: 736-1214 (FTS)
817-773-1711 ext 331 (CML)

UTAH, Salt Lake City 84138
4012 Federal Bldg - 125 S. State St.
Phone: 588-5050 (FTS)
801-524-5051 (CML)

VERMONT, Burlington 05401
1 Burlington Square, Suite 205
Phone: 832-6794 (FTS)
802-862-6501 ext 6261 (CML)

VIRGINIA, Richmond 23240
Federal Bldg., Room 9201
400 N. 8th Street - P.O. Box 10026
Phone: 925-2457 (FTS)
804-782-2457 (CML)

WASHINGTON, Spokane 99201
360 U.S. Courthouse
W. 920 Riverside Avenue
Phone: 439-3711 (FTS)
509-456-3711 (CML)

WEST VIRGINIA, Morgantown 26505
75 High Street, P.O. Box 865
Phone: 923-7151 (FTS)
304-599-7151 (CML)

WISCONSIN, Madison 53711
4601 Hammersley Road
Phone: 364-5351 (FTS)
608-252-5351 (CML)

WYOMING, Casper 82601
Federal Office Bldg, P.O. Box 2440
Phone: 328-5201 (FTS)
307-265-5550 ext 3217 (CML)

TECHNICAL SERVICE CENTERS

MIDWEST

NEBRASKA, Lincoln 68508
Federal Bldg.-U.S. Courthouse, Rm 393
Phone: 541-5346 (FTS)
402-471-5361 (CML)

WEST

OREGON, Portland 97209
511 N.W. Broadway
Phone: 423-2824 (FTS)
503-221-2824 (CML)

NORTHEAST

PENNSYLVANIA, Broomall 19008
1974 Sproul Road
Phone: 596-5783 (FTS)
215-596-5710 (CML)

SOUTH

TEXAS, Ft. Worth 76115
Ft. Worth Federal Center
P.O. Box 6567
Phone: 817-334-5456 (FTS & CML)

CARTOGRAPHIC UNITS

(Not located at TSC)

MARYLAND, Lanham 20782
10000 Aerospace Road
Phone: 301-436-8756 (FTS & CML)

FOOTNOTES

FTS = Federal Telecommunications System Number

CML = Commercial Number

a = Calls to Anchorage, Alaska are made:

Through FTS Seattle, Washington, 399-0150 between 7:30 am - 6:00 pm PST

Through FTS Washington, D.C., (Except Washington, D.C.[f]) 967-1221 when Seattle FTS closed

b = Calls to Hawaii are made:

Through FTS San Francisco, Calif. 556-0220 between 7:00 am - 3:00 pm PST

Through FTS Washington, D.C. (Except Washington, D.C.)[f] 967-1221 when S. F. FTS closed

c = Calls to Amherst are made by calling FTS Boston 223-2100[g]

d = Calls to Puerto Rico are made:

Through Washington, D.C.[g]
202 9-472-6620
From Washington, D.C.
9-472-6620
This is access to overseas operator--then give number desired

e = Calls to West Warwick by calling FTS Providence 528-1000[g]

f = Washington, D.C., calls to Alaska, Hawaii, and Puerto Rico see FTS Users Guide

g = For direct dialing from Washington, D.C. (Hyattsville included) to Amherst and Providence, dial Access Code "8," area code, and number listed for State Conservationist

October 1980

A5-4

LIST OF PUBLISHED SOIL SURVEYS

United States Department of Agriculture
Soil Conservation Service

January 1980

LIST OF PUBLISHED SOIL SURVEYS

The U.S. Department of Agriculture, in cooperation with state agricultural experiment stations and other federal and state agencies, has been making soil surveys and publishing them since 1899. These surveys furnish soil maps and interpretations needed in giving technical assistance to farmers and ranchers, in guiding other decisions about soil selection, use, and management, in planning research and disseminating the results of the research, and they are used in educational programs about soil use and conservation. Sound scientific and technical standards are used in a nationwide system of soil classification, nomenclature, interpretation, and publication.

Soil classification has improved as our knowledge about soils and their potential uses has increased. As agriculture has become more technical, a proper fit between the kind of soil and the combination of practices used has become more critical. Because of this, soils bearing the same names are more narrowly defined in recent surveys than in the older ones.

When soil survey work began in 1899 little was known about the soils of the United States. Since then a great deal has been learned, methods have been improved, and the results of the surveys are more accurate and detailed. For planning farms, engineering structures, parks, urban developments, and other uses of land, the recent published soil surveys are more useful. The older surveys can be of considerable assistance for many users, but their maps are more general than those in recent surveys and some of the interpretations need to be updated.

Published soil surveys contain, in addition to soil maps, general information about the agriculture and climate of the area and descriptions of each kind of soil. They include a discussion of the formation and classification of the soils in the area and also soil laboratory data when available.

Soil surveys published since 1957 contain many different kinds of interpretations for each of the different soils mapped in the area. The kinds of interpretations included in these recent surveys vary with the needs of the area, but the following interpretations are in most of them: Estimated yields of the common agricultural crops under defined levels of management; land-capability interpretations, soil-woodland interpretations, rangeland interpretations, engineering uses of soils, interpretations for community planning, suitability of the soil for drainage and irrigation, suitability of the soil for wildlife and for recreation.

Most of the soil surveys published since 1957 contain soil maps printed on a photomosaic base. The usual map scale is 1:24,000, 1:20,000 or 1:15,840, depending on the needs of the area.

This publication lists those surveys that have been published by the U.S. Department of Agriculture. A few state agencies also publish surveys but, except for nine in Illinois, these are not included in this list.

A soil survey published by the U.S. Department of Agriculture that is still in print can be obtained in one of the following ways:

> Land users in the area surveyed and professional workers who have use for the survey can obtain a free copy from the state or local office of the Soil Conservation Service, from their county agent, or from their congressman. Many libraries keep published soil surveys on file for reference. Also, soil conservation district offices and county agricultural extension offices have copies of local soil surveys that can be used for reference.

Most published soil surveys cover one or more counties and are so named. Where the survey covers only a part of one or more counties, the word "area" is a part of the name. The date in the list is the year the field work was completed for surveys made from 1899 to 1936; from 1937 on it is the year the publication was issued.

Soil surveys are being completed and published at a rapid rate, so this list is always at least a little out of date. For information on the current status of a soil survey not listed herein, inquiry should be made to the State Conservationist, Soil Conservation Service, in the appropriate state. Addresses of State Conservationists are listed on the back of this page.

PUBLISHED SOIL SURVEYS

ALABAMA

*1908 AUTAUGA
1977 AUTAUGA
*1909 BALDWIN
1964 BALDWIN
*1914 BARBOUR
*1908 BIBB
*1905 BLOUNT
*1913 BULLOCK
*1907 BUTLER
*1908 CALHOUN
1961 CALHOUN
*1909 CHAMBERS
1959 CHAMBERS
1924 CHEROKEE
1978 CHEROKEE
*1911 CHILTON
1972 CHILTON
1921 CHOCTAW
*1912 CLARKE
*1915 CLAY
1974 CLAY
*1913 CLEBURNE
1979 CLEBURNE
*1909 COFFEE
1979 COFFEE
*1908 COLBERT
1939 COLBERT
*1912 CONECUH
*1929 COOSA
*1912 COVINGTON
1921 CRENSHAW
*1908 CULLMAN
1962 CULLMAN
*1910 DALE
1960 DALE
*1905 DALLAS
1938 DALLAS
1979 DALLAS
1958 DE KALB
*1911 ELMORE
1955 ELMORE
*1913 ESCAMBIA
1975 ESCAMBIA
*1908 ETOWAH
1978 ETOWAH
*1917 FAYETTE
1965 FAYETTE
*1903 FORT PAYNE AREA
1927 FRANKLIN
1965 FRANKLIN
1920 GENEVA
1977 GENEVA
1923 GREENE
1971 GREENE
*1909 HALE
1939 HALE
*1908 HENRY
*1920 HOUSTON
1968 HOUSTON
*1903 HUNTSVILLE AREA
*1911 JACKSON
1954 JACKSON
*1908 JEFFERSON
*1908 LAMAR
*1905 LAUDERDALE
1931 LAUDERDALE
1977 LAUDERDALE
*1914 LAWRENCE
1959 LAWRENCE
*1906 LEE
1950 LEE
*1914 LIMESTONE
1953 LIMESTONE
*1916 LOWNDES
*1904 MACON
1944 MACON
*1911 MADISON
1958 MADISON
*1920 MARENGO
*1907 MARION
1979 MARION
*1911 MARSHALL
1959 MARSHALL
*1911 MOBILE
1930 MOBILE
*1903 MOBILE AREA
*1916 MONROE
*1905 MONTGOMERY
1926 MONTGOMERY
1960 MONTGOMERY
*1918 MORGAN
1944 MORGAN
*1902 PERRY
1930 PERRY
*1917 PICKENS
*1910 PIKE
*1911 RANDOLPH
1967 RANDOLPH
*1913 RUSSELL
*1917 SAINT CLAIR
*1917 SHELBY
*1904 SUMTER
1943 SUMTER
*1907 TALLADEGA
1974 TALLADEGA
*1909 TALLAPOOSA
*1911 TUSCALOOSA
*1915 WALKER
*1915 WASHINGTON
*1916 WILCOX
1938 WILCOX
1937 WINSTON

ALASKA

1979 ALASKA EXPLORATORY
*1914 ALASKAN RECONNAISSANCE
1963 FAIRBANKS AREA
1977 GOLDSTREAM - NENANA AREA
1971 HOMER-NINILCHIK AREA
*1916 KENAI PENINSULA
1962 KENAI-KASILOF AREA
*1968 MATANUSKA VALLEY AREA
1960 NORTHEASTERN KODIAK ISLAND AREA
1973 SALCHA-BIG DELTA AREA
1973 SUSITNA VALLEY

ARIZONA

1975 APACHE (CENTRAL PART)
1967 BEAVER CREEK AREA
*1921 BENSON AREA
*1927 BUCKEYE-BEARDSLEY AREA
*1941 CASA GRANDE AREA
1974 EAST MARICOPA AND NORTHERN PINAL
*1928 GILA BEND AREA
1964 HOLBROOK SHOW-LOW AREA
1974 LONG VALLEY AREA
1977 MARICOPA (CENTRAL PART)
*1917 MIDDLE GILA VALLEY AREA
*1930 NOGALES AREA
1973 ORGAN PIPE CACTUS NATIONAL MONUMENT
*1928 PARADISE-VERDE AREA
1970 SAFFORD AREA
*1900 SALT RIVER VALLEY AREA
*1926 SALT RIVER VALLEY AREA
*1921 SAN SIMON AREA
1979 SANTA CRUZ AND PARTS OF COCHISE AND PIMA
*1903 SOLMONSVILLE AREA
*1954 SULPHUR SPRINGS VALLEY AREA
1950 THE DUNCAN AREA
*1931 TUCSON AREA
1972 TUCSON-AVRA VALLEY AREA
1938 UPPER GILA VALLEY AREA
*1942 VIRGIN RIVER VALLEY AREA
1976 WILLCOX
*1921 WINSLOW AREA
1976 YAVAPAI, WESTERN PART
*1902 YUMA AREA
*1904 YUMA AREA
1941 YUMA DESERT AREA
*1929 YUMA WELTON AREA

ARKANSAS

1972 ARKANSAS
*1913 ASHLEY
1977 BENTON
*1925 BRADLEY
1961 BRADLEY
1967 CHICOT
1978 CLAY
1968 CLEVELAND
*1914 COLUMBIA
*1907 CONWAY
*1916 CRAIGHEAD
1974 CRITTENDEN
1968 CROSS
1972 DESHA
*1917 DREW
1976 DREW
*1917 FAULKNER
1979 FAULKNER
*1906 FAYETTEVILLE AREA
1971 FRANKLIN
1969 GREENE
*1916 HEMPSTEAD
1979 HEMPSTEAD
*1917 HOWARD
1975 HOWARD
1974 JACKSON
*1915 JEFFERSON
1977 JOHNSON

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1978 LAWRENCE
1977 LEE
*1921 LONOKE
*1903 MILLER
*1914 MISSISSIPPI
1971 MISSISSIPPI
1978 MONROE
*1925 NEVADA
1973 OUACHITA
*1920 PERRY
1974 PHILLIPS
1977 POINSETT
*1913 POPE
*1906 PRAIRIE
*1922 PULASKI
1975 PULASKI
*1911 RECONNAISSANCE OZARK REGION
1979 SALINE
1975 SEBASTIAN
1966 ST. FRANCIS
*1902 STUTTGART AREA
1969 WASHINGTON
1968 WOODRUFF
*1915 YELL

CALIFORNIA

1966 ALAMEDA AREA
*1931 ALTURAS AREA
*1965 AMADOR AREA
*1916 ANAHEIM AREA
1969 ANTELOPE VALLEY AREA
*1924 AUBURN AREA
*1904 BAKERSFIELD AREA
*1945 BAKERSFIELD AREA
*1937 BARSTOW AREA
*1920 BIG VALLEY AREA
1924 BISHOP AREA
*1920 BRAWLEY AREA
*1907 BUTTE VALLEY AREA
*1929 CAPISTRANO AREA
1971 CARSON VALLEY AREA
*1917 CENTRAL SOUTHERN AREA
*1925 CHICO AREA
*1927 CLEAR LAKE AREA
*1923 COACHELLA VALLEY AREA
*1952 COALINGA AREA
*1907 COLUSA AREA
*1939 CONTRA COSTA
1977 CONTRA COSTA
*1931 DIXON AREA
1971 EASTERN FRESNO AREA
1974 EASTERN SANTA CLARA AREA
1964 EASTERN STANISLAUS AREA
*1930 EL CAJON AREA
*1918 EL CENTRO AREA
1974 EL DORADO AREA
*1921 EUREKA AREA
*1900 FRESNO AREA
*1912 FRESNO AREA
*1923 GILROY AREA
1968 GLENN
*1918 GRASS VALLEY AREA
*1901 HANFORD AREA
*1915 HEALDSBURY AREA
*1923 HOLLISTER AREA
*1915 HONEY LAKE AREA
*1901 IMPERIAL AREA
*1903 IMPERIAL AREA
*1903 INDIO AREA
*1924 KING CITY AREA
*1946 KINGS
*1922 LANCASTER AREA
*1910 LIVERMORE AREA
*1937 LODI AREA
*1903 LOS ANGELES AREA
*1916 LOS ANGELES AREA
1952 LOS BANOS AREA
*1901 LOWER SALINAS VALLEY AREA
*1915 LOWER SAN JOAQUIN VALLEY
*1910 MADERA AREA
*1962 MADERA AREA
1974 MARIPOSA AREA
*1909 MARYSVILLE AREA
*1956 MENDOTA AREA
*1914 MERCED AREA
*1962 MERCED AREA
*1916 MIDDLE SAN JOAQUIN VALLEY AREA
*1908 MODESTO-TURLOCK AREA
1978 MONTEREY
1978 NAPA
*1938 NAPA AREA
1975 NEVADA AREA
1948 NEWMAN AREA
*1929 OCEANSIDE AREA
1978 ORANGE AND WESTERN PART OF RIVERSIDE
*1926 OROVILLE AREA
*1908 PAJARO VALLEY AREA
*1922 PALO VERDE AREA
1974 PALO VERDE AREA
*1915 PASADENA AREA
*1928 PASO ROBLEA AREA
*1942 PIXLEY AREA
*1927 PLACERVILLE AREA
*1908 PORTERSVILLE AREA
*1910 RED BLUFF AREA
*1907 REDDING AREA
*1915 RIVERSIDE AREA
*1904 SACRAMENTO AREA
*1941 SACRAMENTO AREA
1954 SACRAMENTO AREA
*1941 SACRAMENTO SAN JOAQUIN DELTA AREA
*1913 SACRAMENTO VALLEY AREA
*1925 SALINAS AREA
1969 SAN BENITO
*1904 SAN BERNARDINO AREA
*1915 SAN DIEGO AREA
1973 SAN DIEGO AREA
*1915 SAN FERNANDO VALLEY AREA
*1914 SAN FRANCISCO BAY AREA
*1901 SAN GABRIEL AREA
*1903 SAN JOSE AREA
*1928 SAN LUIS OBISPO AREA
1961 SAN MATEO AREA
*1900 SANTA ANNA AREA
*1958 SANTA BARBARA AREA
1972 SANTA BARBARA AREA (NORTHERN)
1958 SANTA CLARA AREA
*1944 SANTA CRUZ AREA
*1916 SANTA MARIA AREA
*1927 SANTA YNEZ AREA
1974 SHASTA AREA
*1919 SHASTA VALLEY AREA
1975 SIERRA VALLEY AREA
1977 SOLANO
1972 SONOMA
*1905 STOCKTON AREA
1951 STOCKTON AREA
*1930 SUISAN AREA
1974 SURPRISE VALLEY-HOME CAMP AREA
1974 TAHOE BASIN AREA
1967 TEHAMA
*1943 TRACY AREA
*1914 UKIAH AREA
*1917 UPPER SAN JOAQUIN VALLEY AREA
*1901 VENTURA AREA
*1917 VENTURA AREA
1970 VENTURA AREA
*1921 VICTORVILLE AREA
*1940 VISALIA AREA
1942 WASCO AREA
1971 WESTERN RIVERSIDE AREA
*1918 WILLITS AREA
*1909 WOODLAND AREA
1972 YOLO
*1904 YUMA AREA
*1929 YUMA-WELTON AREA

COLORADO

1974 ADAMS
*1947 AKRON AREA
1973 ALAMOSA AREA
1971 ARAPAHOE
*1926 ARKANSAS VALLEY AREA
1973 BACA
1971 BENT
1975 BOULDER
*1932 BRIGHTON AREA
*1899 CACHE LA POUDRE VALLEY AREA
1974 CASTLE ROCK AREA
1975 CHAFFEE LAKE AREA
1968 CROWLEY
*1967 DELTA-MONTROSE AREA
1966 ELBERT (EASTERN PART)
*1927 FORT COLLINS AREA
*1962 FRASER-ALPINE AREA
*1905 GRAND JUNCTION AREA
*1955 GRAND JUNCTION AREA
*1904 GREELEY AREA
*1929 GREELEY AREA
1975 GUNNISON AREA
1977 LOGAN
*1930 LONGMONT AREA
*1902 LOWER ARKANSAS VALLEY AREA
1978 MESA AREA
1968 MORGAN
1972 OTERO
1971 PHILLIPS
1966 PROWERS
1979 PUEBLO AREA, PARTS OF PUEBLO AND CUSTER
*1903 SAN LUIS VALLEY AREA
1970 SEDGWICK
1977 TAYLOR RIVER AREA
*1961 TROUT CREEK WATERSHED
*1910 UNCOMPAHGRE VALLEY AREA

CONNECTICUT

*1899 CONNECTICUT VALLEY AREA
*1903 CONNECTICUT VALLEY AREA
1962 HARTFORD
1970 LITCHFIELD
1979 NEW HAVEN
*1912 NEW LONDON
1966 TOLLAND
*1911 WINDHAM

DELAWARE

*1903 DOVER AREA
*1918 KENT
1971 KENT
*1915 NEW CASTLE
1970 NEW CASTLE
*1920 SUSSEX
1974 SUSSEX

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DISTRICT OF COLUMBIA

1976 DISTRICT OF COLUMBIA

FLORIDA

*1954 ALACHUA
*1913 BRADFORD
1974 BREVARD
1976 BROWARD AREA
1954 COLLIER
1958 DADE
*1921 DUVAL
1978 DUVAL COUNTY (CITY OF JACKSONVILLE)
*1906 ESCAMBIA
1960 ESCAMBIA
*1918 FLAGLER
*1915 FORT LAUDERDALE AREA
*1915 FRANKLIN
*1903 GADSDEN
1962 GADSDEN
*1904 GAINESVILLE AREA
*1914 HERNANDO
1977 HERNANDO
*1916 HILLSBOROUGH
1958 HILLSBOROUGH
1975 HOLMES
*1913 INDIAN RIVER AREA
1979 JACKSON
*1910 JACKSONVILLE AREA
*1907 JEFFERSON
*1923 LAKE
1975 LAKE AREA
*1905 LEON
*1958 MANATEE
*1909 MARIANNA AREA
1979 MARION AREA
*1912 OCALA AREA
1975 OCALA NATIONAL FOREST AREA
1971 OKEECHOBEE
*1919 ORANGE
1960 ORANGE
1979 OSCEOLA AREA
1978 PALM BEACH AREA
*1913 PINELLAS
1972 PINELLAS
*1927 POLK
*1914 PUTNAM
1959 SARASOTA
1966 SEMINOLE
*1917 ST. JOHNS
1965 SUWANNEE
1965 WASHINGTON

GEORGIA

1975 APPLING AND JEFF DAVIS
*1904 BAINBRIDGE AREA
1976 BALDWIN, JONES AND PUTNAM
1971 BANKS AND STEPHENS
1977 BARROW, HALL AND JACKSON
*1941 BARTOW
*1912 BEN HILL
1969 BEN HILL-IRWIN
1973 BERRIEN AND LANIER
*1922 BIBB
1979 BIBB
*1916 BROOKS
1979 BROOKS AND THOMAS
1974 BRYAN AND CHATHAM
*1910 BULLOCH
1968 BULLOCH
*1917 BURKE
*1919 BUTTS AND HENRY.
*1925 CALHOUN
*1948 CANDLER
*1921 CARROLL
1971 CARROLL AND HARALSON
*1941 CATOOSA
*1911 CHATHAM
*1924 CHATTAHOOCHEE
*1912 CHATTOOGA
1978 CHATTOOGA,FLOYD,AND POLK
1973 CHEROKEE, GILMER, AND PICKENS
*1927 CLARKE
1968 CLARKE-OCONEE
*1914 CLAY
1979 CLAYTON,FAYETTE AND HENRY
*1901 COBB
1973 COBB
*1914 COLQUITT
1975 COLQUITT AND COOK
*1911 COLUMBIA
*1928 COOK
*1901 COVINGTON AREA
*1919 COWETA AND FAYETTE
*1916 CRISP
*1942 DADE
1972 DAWSON, LUMPKIN, AND WHITE
*1939 DECATUR
*1914 DE KALB
*1904 DODGE
*1923 DOOLY
*1912 DOUGHERTY
1968 DOUGHERTY
1961 DOUGLAS
*1918 EARLY
*1928 ELBERT
1979 ELBERT, FRANKLIN AND MADISON
*1923 FANNIN
*1917 FLOYD
1960 FORSYTH
*1903 FORT VALLEY AREA
*1909 FRANKLIN
1958 FULTON
*1911 GLYNN
*1923 GORDON
1965 GORDON
*1908 GRADY
1967 GWINNETT
*1923 HABERSHAM
1963 HABERSHAM
*1941 HALL
*1909 HANCOCK
*1929 HART
1963 HART
1967 HOUSTON AND PEACH
*1914 JACKSON
*1916 JASPER
*1913 JEFF DAVIS
*1930 JEFFERSON
*1923 JENKINS
1968 JENKINS
*1913 JONES
*1925 LAMAR
1972 LAMAR, PIKE, AND UPSON
*1915 LAURENS
*1927 LEE
1978 LEE AND TERRELL
*1917 LOWNDES
1979 LOWNDES
*1918 MADISON
*1937 MCDUFFIE
*1929 MCINTOSH
1961 MCINTOSH
*1916 MERIWETHER
1965 MERIWETHER
*1913 MILLER
1976 MILLER AND SEMINOLE
*1920 MITCHELL
*1920 MONROE
1973 MONTGOMERY, TOOMBS, AND WHEELER
1965 MORGAN
*1922 MUSCOGEE
*1919 OCONEE, MORGAN, AND PUTNAM
*1918 PIERCE
1968 PIERCE
*1909 PIKE
*1914 POLK
*1918 PULASKI
*1926 QUITMAN
*1920 RABUN
*1924 RANDOLPH
*1912 RECONNAISSANCE TATTNALL
*1916 RICHMOND
*1920 ROCKDALE
1974 SCHLEY AND SUMTER
*1920 SCREVEN
*1905 SPALDING
1964 SPALDING
*1913 STEWART
*1910 SUMTER
*1913 TALBOT
*1914 TATTNALL
*1914 TERRELL
*1908 THOMAS
*1909 TIFT
1959 TIFT
*1939 TOOMBS
*1954 TOWNS
1964 TREUTLEN
*1912 TROUP
*1915 TURNER
1963 TWIGGS
*1950 UNION
*1910 WALKER
1964 WALTON
*1915 WASHINGTON
*1906 WAYCROSS AREA
*1926 WAYNE
1965 WAYNE
*1915 WILKES
*1929 WORTH

HAWAII

1973 ISLAND OF HAWAII
1972 KAUAI, OAHU, MAUI, MOLOKAI, AND LANAI
*1955 THE TERRITORY OF HAWAII

IDAHO

*1926 BEAR LAKE VALLEY AREA
*1930 BENEWAH
1973 BINGHAM
*1903 BLACKFOOT AREA
*1943 BLACKFOOT-ABERDEEN AREA
*1901 BOISE AREA
*1939 BONNER
1972 CANYON AREA
1977 FT. HALL AREA
1965 GEM COUNTY AREA
*1929 GOODING AREA
1950 IDAHO FALLS AREA
*1927 JEROME AREA
1971 KOOSKIA
*1919 KOOTENAI
*1915 LATAH
*1902 LEWISTON AREA
1976 MIDDLE FORK PAYETTE RIVER AREA

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*1907 MINIDOKA AREA
*1923 MINIDOKA AREA
1975 MINIDOKA AREA
*1917 NEZ PERCE AND LEWIS
1976 PAYETTE
*1918 PORTNEUF AREA
*1925 SODA SPRINGS BANCROFT AREA
1976 STAR VALLEY AREA
1969 TETON AREA IDAHO-WYOMING
*1921 TWIN FALLS AREA

ILLINOIS

1975 CARROLL (STATE)
*1902 CLAY
*1902 CLINTON
1978 DE KALB
1971 DOUGLAS
1979 DUPAGE COUNTY AND PART OF COOK
1972 EDWARDS AND RICHLAND
1969 GALLATIN
1974 GREENE
1956 HENDERSON (STATE)
1979 JACKSON
1966 JERSEY (STATE)
*1903 JOHNSON
1964 JOHNSON (STATE)
1979 KANE
1979 KANKAKEE
1978 KENDALL
*1903 KNOX
1970 LAKE
1972 LA SALLE (STATE)
1956 LAWRENCE (STATE)
1974 LOGAN
1965 MCHENRY (STATE)
*1903 MCLEAN
1953 MENARD (STATE)
1969 MONTGOMERY
*1904 O'FALLON AREA
1975 POPE, HARDIN AND MASSAC
1968 PULASKI AND ALEXANDER
1977 ROCK ISLAND
1978 SALINE
*1903 SANGAMON
*1902 ST. CLAIR
1978 ST. CLAIR
1976 STEPHENSON (STATE)
*1902 TAZEWELL
1979 UNION
1964 WABASH
*1912 WILL
1962 WILL (STATE)
1959 WILLIAMSON (STATE)
*1903 WINNEBAGO

INDIANA

1921 ADAMS
*1908 ALLEN
1969 ALLEN
1947 BARTHOLOMEW
1976 BARTHOLOMEW
1916 BENTON
*1928 BLACKFORD
*1912 BOONE
1975 BOONE
*1904 BOONEVILLE AREA
1946 BROWN
1958 CARROLL
*1955 CASS
1974 CLARK AND FLOYD
1922 CLAY
*1914 CLINTON
1975 CRAWFORD
1974 DAVIESS
1910 DECATUR
*1913 DELAWARE
1972 DELAWARE
1937 DUBOIS
*1914 ELKHART
1974 ELKHART
1960 FAYETTE AND UNION
1966 FOUNTAIN
1950 FRANKLIN
1946 FULTON
1922 GIBSON
*1915 GRANT
*1906 GREENE
*1912 HAMILTON
1978 HAMILTON
1925 HANCOCK
1978 HANCOCK
1975 HARRISON
1913 HENDRICKS
1974 HENDRICKS
1971 HOWARD
1940 JENNINGS
1976 JENNINGS
*1948 JOHNSON
1979 JOHNSON
1943 KNOX
*1922 KOSCIUSKO
1944 LA PORTE
*1917 LAKE
1972 LAKE
*1922 LAWRENCE
*1903 MADISON
1967 MADISON
*1907 MARION
1978 MARION
*1904 MARSHALL
1946 MARTIN
1927 MIAMI
1979 MIAMI
*1922 MONROE
*1912 MONTGOMERY
1950 MORGAN
*1905 NEWTON
*1955 NEWTON
*1953 NOBLE
1977 NOBLE
1930 OHIO AND SWITZERLAND
*1964 OWEN
1967 PARKE
1969 PERRY
1938 PIKE
*1916 PORTER
*1902 POSEY
1979 POSEY
1968 PULASKI
1925 PUTNAM
1931 RANDOLPH
*1937 RUSH
*1904 SCOTT
1962 SCOTT
1974 SHELBY
1973 SPENCER
*1950 ST. JOSEPH
1977 ST. JOSEPH
*1915 STARKE
1940 STEUBEN
1971 SULLIVAN
*1905 TIPPECANOE
1959 TIPPECANOE
*1912 TIPTON
1944 VANDERBURGH
1976 VANDERBURGH
1930 VERMILLION
1978 VERMILLION
1974 VIGO
*1914 WARREN
1979 WARRICK
1939 WASHINGTON
1925 WAYNE
*1915 WELLS
*1915 WHITE

IOWA

*1919 ADAIR
1963 ADAMS
1958 ALLAMAKEE
*1923 APPANOOSE
1977 APPANOOSE
*1940 AUDUBON
*1921 BENTON
*1917 BLACK HAWK
1978 BLACK HAWK
*1920 BOONE
*1913 BREMER
1967 BREMER
*1926 BUCHANAN
*1917 BUENA VISTA
1977 BUENA VISTA
*1928 BUTLER
*1930 CALHOUN
*1926 CARROLL
1969 CASS
*1919 CEDAR
*1903 CERRO GORDO
*1940 CERRO GORDO
*1924 CHEROKEE
*1927 CHICKASAW
*1923 CLARKE
*1916 CLAY
1969 CLAY
*1925 CLAYTON
*1915 CLINTON
*1928 CRAWFORD
1973 CRAWFORD
*1920 DALLAS
*1940 DAVIS
*1939 DECATUR
*1922 DELAWARE
*1921 DES MOINES
*1920 DICKINSON
*1921 DUBUQUE
*1902 DUBUQUE AREA
*1920 EMMET
*1919 FAYETTE
1979 FAYETTE
*1922 FLOYD
*1930 FRANKLIN
*1924 FREMONT
1975 FREMONT
*1921 GREENE
*1921 GRUNDY
1977 GRUNDY
*1929 GUTHRIE
1974 GUTHRIE
*1917 HAMILTON
*1930 HANCOCK
*1920 HARDIN
*1923 HARRISON
1976 HARRISON
*1917 HENRY
*1935 HOWARD
1974 HOWARD
1961 HUMBOLDT
*1939 IDA
1967 IOWA
*1941 JACKSON
*1921 JASPER
1979 JASPER
*1922 JEFFERSON
1960 JEFFERSON
*1919 JOHNSON
*1924 JONES
1971 KEOKUK
*1925 KOSSUTH
*1914 LEE

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1979 LEE
*1917 LINN
1975 LINN
*1918 LOUISA
1960 LUCAS
*1927 LYON
1978 LYON
*1918 MADISON
1975 MADISON
*1919 MAHASKA
1977 MAHASKA
*1939 MARION
*1919 MARSHALL
*1930 MILLS
*1916 MITCHELL
1975 MITCHELL
1959 MONONA
*1931 MONROE
*1917 MONTGOMERY
*1914 MUSCATINE
*1921 O'BRIEN
*1940 OSCEOLA
*1921 PAGE
1978 PAGE
*1918 PALO ALTO
1977 PALO ALTO
*1923 PLYMOUTH
1976 PLYMOUTH
*1928 POCAHONTAS
*1918 POLK
1960 POLK
*1914 POTTAWATTAMIE
*1929 POWESHIEK
*1916 RINGGOLD
*1924 SAC
1979 SAC
*1915 SCOTT
1961 SHELBY
*1915 SIOUX
*1903 STORY
*1941 STORY
*1904 TAMA
1950 TAMA
1954 TAYLOR
*1927 UNION
1978 UNION
*1915 VAN BUREN
1962 VAN BUREN
*1917 WAPELLO
*1925 WARREN
1978 WARREN
*1932 WASHINGTON
*1918 WAYNE
1971 WAYNE
*1914 WEBSTER
1975 WEBSTER
*1918 WINNEBAGO
*1922 WINNESHIEK
1968 WINNESHIEK
*1920 WOODBURY
1972 WOODBURY
*1922 WORTH
1976 WORTH
*1919 WRIGHT

KANSAS

*1904 ALLEN
*1938 ALLEN
1978 ALLEN
1977 ANDERSON
1977 BARBER
*1931 BOURBON
*1905 BROWN
1960 BROWN
1975 BUTLER
1974 CHASE
1976 CHAUTAUQUA
*1912 CHEROKEE
*1926 CLAY
1976 CLOUD
*1915 COWLEY
*1928 CRAWFORD
1973 CRAWFORD
*1927 DONIPHAN
1977 DOUGLAS
1973 EDWARDS
1975 ELLIS
1965 FINNEY
1965 FORD
*1904 GARDEN CITY AREA
1960 GEARY
1978 GOVE
1959 GRANT
1968 GRAY
1961 GREELEY
*1912 GREENWOOD
1961 HAMILTON
1971 HARPER
1974 HARVEY
1968 HASKELL
1973 HODGEMAN
1979 JACKSON
1977 JEFFERSON
*1912 JEWELL
*1928 JOHNSON
1979 JOHNSON
1963 KEARNY
*1938 KINGMAN
1979 KINGMAN
*1926 LABETTE
1972 LANE
*1919 LEAVENWORTH
1977 LEAVENWORTH AND WYANDOTT
1964 LOGAN
*1930 MARION
1977 MEADE
*1913 MONTGOMERY
1974 MORRIS
1963 MORTON
*1930 NEOSHO
1977 NESS
1977 NORTON
1977 OSBORNE
*1903 PARSONS AREA
1978 PAWNEE
1968 PRATT
*1911 RENO
1966 RENO
1967 REPUBLIC
1974 RICE
*1906 RILEY
1975 RILEY AND PART OF GEARY
*1903 RUSSELL
1959 SALINE
1965 SCOTT
1979 SEDGWICK
1965 SEWARD
*1911 SHAWNEE
1970 SHAWNEE
1973 SHERMAN
1978 SMITH
1978 STAFFORD
1961 STANTON
1961 STEVENS
1979 SUMNER
*1910 WESTERN KANSAS RECONNAISSANCE
1965 WICHITA
*1902 WICHITA AREA
*1927 WILSON
*1931 WOODSON
1977 WOODSON

KENTUCKY

1964 ADAIR
1969 BARREN
1963 BATH
1976 BALLARD AND MCCRACKEN
1973 BOONE, CAMPBELL, AND KENTON
1979 BOYD AND GREENUP
1966 CALDWELL
*1945 CALLOWAY
1973 CALLOWAY AND MARSHALL
1976 CARROLL, GALLATIN, AND OWEN
*1912 CHRISTIAN
1964 CLARK
1974 DAVIESS AND HANCOCK
1965 ELLIOTT
1974 ESTILL AND LEE
*1931 FAYETTE
1968 FAYETTE
1965 FOURTEEN CO. EASTERN KY. RECONNAISSANCE
1964 FULTON
*1921 GARRARD
1953 GRAVES
1972 GRAYSON
1979 HARDIN AND LARUE
1968 HARRISON
1967 HENDERSON
1977 HOPKINS
1966 JEFFERSON
*1915 JESSAMINE
*1919 LOGAN
1975 LOGAN
*1905 MADISON
1973 MADISON
*1950 MARSHALL
*1903 MASON
1970 MC CREARY-WHITLEY AREA
*1905 MCCRACKEN
1974 MENIFEE AND ROWAN AND NORTHWESTERN MORGAN
*1930 MERCER
1967 METCALFE
*1920 MUHLENBERG
1971 NELSON
1977 OLDHAM
1974 PULASKI
*1910 ROCKCASTLE
*1903 SCOTT
1977 SCOTT
*1916 SHELBY
*1902 UNION
*1904 WARREN

LOUISIANA

*1903 ACADIA
1962 ACADIA
1976 ASCENSION
1978 ASSUMPTION
*1928 BEAUREGARD
*1908 BIENVILLE
*1962 BOSSIER
*1906 CADDO
*1910 CONCORDIA
*1904 DE SOTO
*1908 EAST AND WEST CARROLL
*1906 EAST BATON ROUGE
1968 EAST BATON ROUGE
*1912 EAST FELICIANA
1974 EVANGELINE
*1911 IBERIA
1978 IBERIA
1977 IBERVILLE
*1918 LA SALLE
*1915 LAFAYETTE
1977 LAFAYETTE
*1901 LAKE CHARLES AREA

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*1909 LINCOLN
*1931 LIVINGSTON
*1921 NATCHITOCHES
*1903 NEW ORLEANS AREA
*1903 OUACHITA
1974 OUACHITA
*1916 RAPIDES
*1919 SABINE
1973 ST. JAMES AND ST. JOHN THE BAPTIST
*1917 ST. MARTIN
1977 ST. MARTIN
*1959 ST. MARY
*1905 TANGIPAHOA
*1968 TENSAS
*1960 TERREBONNE
*1922 WASHINGTON
*1914 WEBSTER
1977 WEST CARROLL
*1907 WINN

MAINE

1970 ANDROSCOGGIN AND SAGADAHOC
*1917 AROOSTOOK
1964 AROOSTOOK NORTHEASTERN PART
1964 AROOSTOOK SOUTHERN PART
*1908 CARIBOU AREA
*1915 CUMBERLAND
1974 CUMBERLAND
1978 KENNEBEC
*1909 ORONO AREA
*1963 PENOBSCOT
1972 SOMERSET (SOUTHERN PART)
*1955 WALDO
*1952 YORK

MARYLAND

*1921 ALLEGANY
1977 ALLEGANY
*1909 ANNE ARUNDEL
*1929 ANNE ARUNDEL
1973 ANNE ARUNDEL
*1917 BALTIMORE
1974 BALTIMORE
*1900 CALVERT
*1929 CALVERT
1971 CALVERT
*1929 CAROLINE
1964 CAROLINE
*1919 CARROLL
1969 CARROLL
*1900 CECIL
*1927 CECIL
1973 CECIL
*1918 CHARLES
1974 CHARLES
*1922 DORCHESTER
*1963 DORCHESTER
*1907 EASTON AREA
*1919 FREDERICK
1960 FREDERICK
*1922 GARRETT
1974 GARRETT
*1901 HARFORD
*1927 HARFORD
1975 HARFORD AREA
*1914 HOWARD
1968 HOWARD
*1900 KENT
*1933 KENT
*1914 MONTGOMERY
1961 MONTGOMERY
*1901 PRINCE GEORGES
*1925 PRINCE GEORGES
1967 PRINCE GEORGES
*1931 QUEEN ANNES
1966 QUEEN ANNES
*1920 SOMERSET
1966 SOMERSET
*1900 ST. MARYS
*1923 ST. MARYS
1978 ST. MARYS
*1929 TALBOT
1970 TALBOT
*1917 WASHINGTON
1962 WASHINGTON
*1921 WICOMICO
1970 WICOMICO
*1903 WORCESTER
*1924 WORCESTER
1973 WORCESTER

MASSACHUSETTS

*1923 BERKSHIRE
1978 BRISTOL, NORTHERN PART
*1899 CONNECTICUT VALLEY AREA
*1903 CONNECTICUT VALLEY AREA
*1925 DUKES AND NANTUCKET
*1925 ESSEX
*1929 FRANKLIN
1967 FRANKLIN
1978 HAMPDEN, CENTRAL PART
*1928 HAMPDEN AND HAMPSHIRE
*1924 MIDDLESEX
1979 NANTUCKET
*1920 NORFOLK, BRISTOL, AND BARNSTABLE
*1911 PLYMOUTH
1969 PLYMOUTH
*1922 WORCESTER

MICHIGAN

1929 ALGER
*1901 ALLEGAN
*1904 ALMA AREA
1924 ALPENA
1923 ANTRIM
1978 ANTRIM
1967 ARENAC
1924 BARRY
1931 BAY
*1902 BERRIEN
*1928 BRANCH
*1916 CALHOUN
*1906 CASS
1974 CHARLEVOIX
1939 CHEBOYGAN
1927 CHIPPEWA
1979 CLARE
1962 CLINTON
1978 CLINTON
1927 CRAWFORD
1977 DELTA AND HIAWATHA NATIONAL FOREST
*1930 EATON
1978 EATON
1973 EMMET
*1912 GENESEE
1972 GENESEE
1972 GLADWIN
1966 GRAND TRAVERSE
1979 GRATIOT
1924 HILLSDALE
1961 INGHAM
1979 INGHAM
1967 IONIA
1937 IRON
1925 ISABELLA
1926 JACKSON
*1922 KALAMAZOO
1979 KALAMAZOO
1927 KALKASKA
1926 KENT
1972 LAPEER
1973 LEELANAU
1961 LENAWEE
*1923 LIVINGSTON
1974 LIVINGSTON
1929 LUCE
*1923 MACOMB
1971 MACOMB
1922 MANISTEE
1939 MASON
1927 MECOSTA
1925 MENOMINEE
1950 MIDLAND
1979 MIDLAND
1960 MONTCALM
1930 MONTMORENCY
*1904 MUNISING AREA
*1924 MUSKEGON
1968 MUSKEGON
1951 NEWAYGO
1938 OCEANA
1923 OGEMAW
1969 OSCEOLA
1931 OSCODA
*1922 OTTAWA
1972 OTTAWA
*1904 OWOSSO AREA
*1905 OXFORD AREA
*1903 PONTIAC AREA
*1940 PRESQUE ISLE
*1921 RECONNAISSANCE ONTONAGON
1924 ROSCOMMON
1938 SAGINAW
*1904 SAGINAW AREA
1961 SANILAC
1939 SCHOOLCRAFT
1974 SHIAWASSEE
*1929 ST. CLAIR
1974 ST. CLAIR
*1921 ST. JOSEPH
1926 TUSCOLA
*1922 VAN BUREN
1930 WASHTENAW
1977 WASHTENAW
1977 WAYNE AREA
*1908 WEXFORD

MINNESOTA

*1916 ANOKA
1977 ANOKA
1977 BENTON
*1906 BLUE EARTH
1979 BLUE EARTH
1978 CARLTON
*1905 CARLTON AREA
1968 CARVER
1979 COTTONWOOD
*1906 CROOKSTON AREA
1965 CROW WING
1960 DAKOTA
1961 DODGE
1975 DOUGLAS
1957 FARIBAULT
1958 FILLMORE
*1913 GOODHUE
1976 GOODHUE
1978 GRANT
*1929 HENNEPIN
1974 HENNEPIN
*1929 HOUSTON
1930 HUBBARD
1958 ISANTI
*1923 JACKSON
*1939 KANABEC

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1978 KAWISHIWI AREA
1979 KITTSON
*1974 LAC QUI PARLE
*1926 LAKE OF THE WOODS (RECONNAISSANCE)
*1954 LE SUEUR
1970 LINCOLN
1979 LYON
*1903 MARSHALL AREA
*1955 MCLEOD
*1927 MILLE LACS
*1958 NICOLLET
1975 NOBLES
1974 NORMAN
*1923 OLMSTED
*1914 PENNINGTON
*1941 PINE
1976 PIPESTONE
1972 POPE
*1914 RAMSEY
*1939 RED RIVER VALLEY AREA
*1909 RICE
1975 RICE
1949 ROCK
1942 ROSEAU
1959 SCOTT
1968 SHERBURNE
1973 STEELE
*1919 STEVENS
1971 STEVENS
1973 SWIFT
1965 WABASHA
*1926 WADENA
1965 WASECA
1968 WRIGHT

MISSISSIPPI

*1919 ADAMS
1979 ADAMS
*1921 ALCORN
1971 ALCORN
*1917 AMITE
1976 AMITE
1977 BENTON
*1904 BILOXI AREA
1958 BOLIVAR
1965 CALHOUN
*1915 CHICKASAW
1974 CHICKASAW
*1920 CHOCTAW
*1926 CLAIBORNE
1963 CLAIBORNE
*1914 CLARKE
1965 CLARKE
*1909 CLAY
1976 CLAY
*1915 COAHOMA
1959 COAHOMA
*1918 COVINGTON
1965 COVINGTON
*1905 CRYSTAL SPRINGS AREA
1959 DE SOTO
*1911 FORREST
1979 FORREST
*1922 GEORGE
1971 GEORGE
*1932 GREENE
*1915 GRENADA
1967 GRENADA
*1930 HANCOCK
*1924 HARRISON
1975 HARRISON
*1916 HINDS
1979 HINDS
*1908 HOLMES
1959 HUMPHREYS
1961 ISSAQUENA
1979 ITAWAMBA
*1927 JACKSON
1964 JACKSON
*1904 JACKSON AREA
*1907 JASPER
1979 JASPER
*1915 JEFFERSON DAVIS
1976 JEFFERSON DAVIS
*1913 JONES
*1912 LAFAYETTE
*1919 LAMAR
1975 LAMAR
*1910 LAUDERDALE
1978 LAWRENCE
*1916 LEE
1973 LEE
1959 LEFLORE
*1912 LINCOLN
1963 LINCOLN
*1911 LOWNDES
1979 LOWNDES
*1917 MADISON
*1938 MARION
1972 MARSHALL
*1903 MCNEILL AREA
*1908 MONROE
1966 MONROE
*1906 MONTGOMERY
1975 MONTGOMERY
*1916 NEWTON
1960 NEWTON
*1910 NOXUBEE
*1907 OKTIBBEHA
1973 OKTIBBEHA
1963 PANOLA
*1918 PEARL RIVER
*1922 PERRY
*1918 PIKE
1968 PIKE
*1906 PONTOTOC
1973 PONTOTOC
*1907 PRENTISS
1957 PRENTISS
1958 QUITMAN
*1926 RANKIN
*1909 SCRANTON AREA
1962 SHARKEY
*1919 SIMPSON
*1902 SMEDES AREA
*1920 SMITH
1959 SUNFLOWER
1970 TALLAHATCHIE
1967 TATE
1966 TIPPAH
*1944 TISHOMINGO
1956 TUNICA
1979 UNION
1968 WALTHALL
*1912 WARREN
1964 WARREN
1961 WASHINGTON
*1911 WAYNE
1978 WEBSTER
*1913 WILKINSON
*1912 WINSTON
1978 YALOBUSHA
1975 YAZOO
*1901 YAZOO AREA

MISSOURI

*1921 ANDREW
*1909 ATCHISON
*1916 BARRY
*1912 BARTON
1974 BARTON
*1908 BATES
1962 BOONE
*1915 BUCHANAN
*1921 CALDWELL
1974 CALDWELL
*1916 CALLAWAY
*1910 CAPE GIRARDEAU
*1912 CARROLL
*1912 CASS
*1909 CEDAR
*1918 CHARITON
*1920 COLE
*1909 COOPER
*1905 CRAWFORD
1964 DAVIESS
*1914 DE KALB
1977 DE KALB
1971 DENT
*1914 DUNKLIN
1979 DUNKLIN
*1911 FRANKLIN
*1913 GREENE
*1914 GRUNDY
*1914 HARRISON
1979 HARRISON
1976 HENRY
1953 HOLT
1978 HOWARD
*1902 HOWELL
*1910 JACKSON
1954 JASPER
*1914 JOHNSON
*1917 KNOX
1979 KNOX, MONROE AND SHELBY
*1911 LACLEDE
*1920 LAFAYETTE
1975 LAFAYETTE
*1923 LAWRENCE
*1917 LINCOLN
*1945 LINN
1956 LIVINGSTON
*1911 MACON
*1910 MARION
1975 MARK TWAIN NATIONAL FOREST AREA
*1912 MILLER
*1921 MISSISSIPPI
1964 MONITEAU
1978 MONTGOMERY AND WARREN
1977 NEW MADRID
*1915 NEWTON
*1913 NODAWAY
*1904 O'FALLON AREA
*1910 PEMISCOT
1971 PEMISCOT
*1913 PERRY
*1914 PETTIS
*1912 PIKE
*1911 PLATTE
*1926 POLK
*1906 PUTNAM
*1913 RALLS
*1922 RAY
*1911 RECONNAISSANCE OZARK REGION
*1918 REYNOLDS
*1915 RIPLEY
*1919 SALINE
*1905 SCOTLAND
1975 SCOTLAND
*1903 SHELBY
*1956 ST. CHARLES
*1918 ST. FRANCOIS
*1919 ST. LOUIS
*1912 STODDARD
*1917 TEXAS
1977 VERNON
*1904 WEBSTER
1968 WORTH

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MONTANA

1977 BIG HORN AREA
*1944 BIG HORN VALLEY AREA
*1902 BILLINGS AREA
*1914 BITTERROOT VALLEY AREA
1959 BITTERROOT VALLEY AREA
1977 BROADWATER AREA
1975 CARBON AREA
1953 CENTRAL MONTANA (RECONNAISSANCE)
1976 DAWSON
*1905 GALLATIN VALLEY AREA
*1931 GALLATIN VALLEY AREA
1967 JUDITH BASIN AREA
*1929 LOWER FLATHEAD VALLEY AREA
*1939 LOWER YELLOWSTONE VALLEY AREA
1940 MIDDLE YELLOWSTONE VALLEY AREA
*1928 MILK RIVER AREA
*1929 NORTHERN PLAINS OF MONTANA RECONNAISSANCE
1971 POWDER RIVER AREA
1977 SHERIDAN
1967 TREASURE
1960 UPPER FLATHEAD VALLEY AREA
*1943 UPPER MUSSELSHELL VALLEY AREA
1958 WIBAUX
1972 YELLOWSTONE

NEBRASKA

*1923 ADAMS
1974 ADAMS
*1921 ANTELOPE
1978 ANTELOPE
1977 ARTHUR AND GRANT
*1919 BANNER
*1954 BLAINE
*1921 BOONE
1972 BOONE
*1916 BOX BUTTE
*1937 BOYD
1979 BOYD
*1938 BROWN
*1924 BUFFALO
1974 BUFFALO
*1922 BURT
*1924 BUTLER
*1913 CASS
*1941 CASS
*1928 CEDAR
*1917 CHASE
1956 CHERRY
*1918 CHEYENNE
*1927 CLAY
*1930 COLFAX
*1922 CUMING
1975 CUMING
*1926 CUSTER
*1919 DAKOTA
1976 DAKOTA
*1915 DAWES
1977 DAWES
*1922 DAWSON
1978 DAWSON
*1921 DEUEL
1965 DEUEL
*1929 DIXON
1978 DIXON
*1916 DODGE
1979 DODGE
*1913 DOUGLAS
1975 DOUGLAS AND SARPY
*1931 DUNDY
1963 DUNDY
*1916 FILLMORE
*1916 FORT LARAMIE AREA
*1926 FRANKLIN
1978 FRANKLIN
*1939 FRONTIER
1978 FRONTIER
*1930 FURNAS
1979 FURNAS
*1914 GAGE
1964 GAGE
*1924 GARDEN
*1938 GARFIELD
*1938 GOSPER
*1903 GRAND ISLAND AREA
*1937 GREELEY
*1916 HALL
1962 HALL
*1927 HAMILTON
*1930 HARLAN
1974 HARLAN
*1938 HAYES
*1930 HITCHCOCK
1970 HITCHCOCK
*1938 HOLT
1964 HOOKER
*1920 HOWARD
1974 HOWARD
*1921 JEFFERSON
1975 JEFFERSON
*1920 JOHNSON
*1923 KEARNEY
*1904 KEARNEY AREA
*1926 KEITH
*1937 KEYA PAHA
*1916 KIMBALL
1962 KIMBALL
*1930 KNOX
*1906 LANCASTER
1948 LANCASTER
*1926 LINCOLN
1978 LINCOLN
1975 LOGAN
*1937 LOUP
*1920 MADISON
1969 MCPHERSON
*1922 MERRICK
*1917 MORRILL
*1922 NANCE
1960 NANCE
*1914 NEMAHA
*1907 NORTH PLATTE AREA
*1925 NUCKOLLS
1978 NUCKOLLS
*1912 OTOE
1950 OTOE
*1920 PAWNEE
1976 PAWNEE
*1921 PERKINS
*1917 PHELPS
1973 PHELPS
*1928 PIERCE
1976 PIERCE
*1923 PLATTE
*1915 POLK
1974 POLK
*1919 RED WILLOW
1967 RED WILLOW
*1915 RICHARDSON
1974 RICHARDSON
*1937 ROCK
*1928 SALINE
*1905 SARPY
*1939 SARPY
*1913 SAUNDERS
1965 SAUNDERS
*1913 SCOTTS BLUFF
1968 SCOTTS BLUFF
*1914 SEWARD
1974 SEWARD
*1918 SHERIDAN
*1931 SHERMAN
*1919 SIOUX
*1929 STANTON
*1903 STANTON AREA
*1927 THAYER
1968 THAYER
1965 THOMAS
*1914 THURSTON
1972 THURSTON
*1932 VALLEY
*1915 WASHINGTON
1964 WASHINGTON
*1917 WAYNE
1975 WAYNE
*1923 WEBSTER
1974 WEBSTER
*1911 WESTERN NEBRASKA RECONNAISSANCE
*1937 WHEELER
*1928 YORK
1977 YORK

NEVADA

1979 CARSON CITY AREA
1971 CARSON VALLEY AREA
*1909 FALLON AREA
1975 FALLON-FERNLEY AREA
1967 LAS VEGAS AND ELDORADO VALLEYS AREA
*1923 LAS VEGAS AREA
1965 LOVELOCK AREA
1976 MEADOW VALLEY AREA
*1923 MOAPA VALLEY AREA
1968 PAHRANAGAT-PENOYER AREA
1974 SURPRISE VALLEY-HOME CAMP
1974 TAHOE BASIN

NEW HAMPSHIRE

1968 BELKNAP
1977 CARROLL
1949 CHESHIRE AND SULLIVAN
1943 COOS
1939 GRAFTON
1953 HILLSBOROUGH
*1906 MERRIMACK
1965 MERRIMACK
*1909 NASHUA AREA
*1959 ROCKINGHAM
*1949 STRAFFORD
1973 STRAFFORD

NEW JERSEY

1978 ATLANTIC
*1917 BELVIDERE AREA
*1925 BERGEN AREA
*1919 BERNARDSVILLE AREA
1971 BURLINGTON
1966 CAMDEN
*1915 CAMDEN AREA
*1926 CAMDEN AREA
1977 CAPE MAY
*1919 CHATSWORTH AREA
1978 CUMBERLAND
*1913 FREEHOLD AREA
*1927 FREEHOLD AREA
1962 GLOUCESTER
1974 HUNTERDON
1972 MERCER
*1917 MILLVILLE AREA

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1976 MORRIS
1975 PASSAIC
1969 SALEM
*1901 SALEM AREA
*1923 SALEM AREA
1976 SOMERSET
1975 SUSSEX
*1911 SUSSEX AREA
*1902 TRENTON AREA
*1921 TRENTON AREA
1979 WARREN

NEW MEXICO

1977 BERNALILLO AND PARTS OF
SANDOVAL AND VALENCIA
1958 BLUEWATER AREA
1968 CABEZON AREA
1958 CURRY
*1928 DEMING AREA
1971 EDDY AREA
*1930 FORT SUMNER AREA
1973 HARDING
1973 HIDALGO
1974 LEA
*1932 LOVINGTON AREA
1976 MESCALERO-APACHE AREA
*1912 MESILLA VALLEY AREA
*1912 MIDDLE RIO GRANDE
VALLEY AREA
*1899 PECOS VALLEY
*1959 PORTALES AREA
*1930 RINCON AREA
1967 ROOSEVELT
*1933 ROSWELL AREA
1975 SANTA FE AREA
*1929 SOCORRO AND RIO PUERCO
AREAS
1967 SOUTHWEST QUAY AREA
*1950 THE DUNCAN AREA
1970 TORRANCE AREA
1974 TUCUMCARI AREA
1975 VALENCIA
1976 WHITE SANDS MISSILE
RANGE
1967 ZUNI MOUNTAIN AREA

NEW YORK

*1942 ALBANY AND SCHENECTADY
*1956 ALLEGANY
*1904 AUBURN AREA
*1902 BIGFLATS AREA
*1905 BINGHAMTON AREA
*1932 BROOME
1971 BROOME
*1940 CATTARAUGUS
*1922 CAYUGA
1971 CAYUGA
*1914 CHAUTAUQUA
*1932 CHEMUNG
1973 CHEMUNG
*1918 CHENANGO
*1914 CLINTON
*1923 COLUMBIA
*1916 CORTLAND
1961 CORTLAND
*1930 DELAWARE
*1907 DUTCHESS
1955 DUTCHESS
*1929 ERIE
1958 FRANKLIN
*1922 GENESEE
1969 GENESEE
1975 HERKIMER
*1923 HERKIMER AREA
*1911 JEFFERSON
1960 LEWIS
*1908 LIVINGSTON
*1956 LIVINGSTON
*1903 LONG ISLAND AREA
*1902 LYONS AREA
*1906 MADISON
*1910 MONROE
*1938 MONROE
1973 MONROE
*1908 MONTGOMERY
1978 MONTGOMERY AND
SCHENECTADY
*1906 NIAGARA
*1947 NIAGARA
1972 NIAGARA
*1913 ONEIDA
*1938 ONONDAGA
1977 ONONDAGA
*1910 ONTARIO
1958 ONTARIO AND YATES
*1912 ORANGE
*1939 ORLEANS
1977 ORLEANS
*1917 OSWEGO
*1940 OTSEGO
*1937 RENSSELAER
*1917 SARATOGA
*1915 SCHOHARIE
1969 SCHOHARIE
1979 SCHUYLER
*1942 SENECA
1972 SENECA
*1925 ST. LAWRENCE
*1931 STEUBEN
1978 STEUBEN
1975 SUFFOLK
*1928 SUFFOLK AND NASSAU
1946 SULLIVAN
*1903 SYRACUSE AREA
*1953 TIOGA
*1905 TOMPKINS
*1920 TOMPKINS
1965 TOMPKINS
*1940 ULSTER
1979 ULSTER
*1909 WASHINGTON
1975 WASHINGTON
*1919 WAYNE
1978 WAYNE
*1901 WESTFIELD AREA
*1919 WHITE PLAINS AREA
*1938 WYOMING
1974 WYOMING
*1916 YATES

NORTH CAROLINA

*1901 ALAMANCE
1960 ALAMANCE
*1915 ALLEGHANY
1973 ALLEGHANY
*1915 ANSON
*1912 ASHE
*1903 ASHEVILLE AREA
*1955 AVERY
*1917 BEAUFORT
*1918 BERTIE
*1914 BLADEN
*1937 BRUNSWICK
*1920 BUNCOMBE
*1954 BUNCOMBE
*1926 BURKE
*1910 CABARRUS
*1917 CALDWELL
*1923 CAMDEN AND CURRITUCK
*1938 CARTERET
*1901 CARY AREA
*1908 CASWELL
1975 CATAWBA
*1937 CHATHAM
*1921 CHEROKEE
*1951 CHEROKEE
*1906 CHOWAN
*1941 CLAY
*1916 CLEVELAND
*1915 COLUMBUS
*1929 CRAVEN
*1903 CRAVEN AREA
*1922 CUMBERLAND
*1915 DAVIDSON
*1927 DAVIE
*1905 DUPLIN
1959 DUPLIN
*1920 DURHAM
1976 DURHAM
*1907 EDGECOMBE
1979 EDGECOMBE
*1913 FORSYTH
1976 FORSYTH
*1931 FRANKLIN
*1909 GASTON
*1929 GATES
*1953 GRAHAM
*1910 GRANVILLE
*1924 GREENE
*1904 GREENVILLE AREA
*1920 GUILFORD
1977 GUILFORD
*1916 HALIFAX
*1916 HARNETT
*1922 HAYWOOD
*1954 HAYWOOD
*1907 HENDERSON
*1943 HENDERSON
*1916 HERTFORD
*1902 HICKORY AREA
*1918 HOKE
1964 IREDELL
*1948 JACKSON
*1911 JOHNSTON
*1938 JONES
*1909 LAKE MATTAMUSKEET AREA
*1933 LEE
*1927 LENOIR
1977 LENOIR
*1914 LINCOLN
*1929 MACON
*1956 MACON
*1942 MADISON
*1928 MARTIN
*1910 MECKLENBURG
*1952 MITCHELL
*1930 MONTGOMERY
*1919 MOORE
*1902 MT. MITCHELL AREA
*1926 NASH
*1906 NEW HANOVER
1977 NEW HANOVER
*1925 NORTHAMPTON
*1921 ONSLOW
*1918 ORANGE
1977 ORANGE
*1937 PAMLICO
1957 PASQUOTANK
*1912 PENDER
*1905 PERQUIMANS AND
PASQUOTANK
*1928 PERSON
*1909 PITT
1974 PITT
*1923 POLK
*1900 RALEIGH TO NEWBERN
*1913 RANDOLPH
*1911 RICHMOND
*1908 ROBESON
1978 ROBESON
*1926 ROCKINGHAM

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*1914 ROWAN
*1924 RUTHERFORD
*1923 SAMPSON
*1909 SCOTLAND
1967 SCOTLAND
*1916 STANLY
*1901 STATESVILLE AREA
*1940 STOKES
*1937 SURRY
*1947 SWAIN
*1906 TRANSYLVANIA
*1948 TRANSYLVANIA
1974 TRANSYLVANIA
*1920 TYRRELL
*1914 UNION
*1918 VANCE
*1914 WAKE
1970 WAKE
*1942 WARREN
*1932 WASHINGTON
*1928 WATAUGA
1958 WATAUGA
*1915 WAYNE
1974 WAYNE
*1918 WILKES
*1925 WILSON
*1924 YADKIN
1962 YADKIN
*1952 YANCEY

NORTH DAKOTA

*1912 BARNES
1944 BILLINGS
*1915 BOTTINEAU
1975 BOWMAN
1974 BURLEIGH
*1904 CANDO AREA
*1905 CARRINGTON AREA
*1924 CASS
*1914 DICKEY
1977 EDDY AND PARTS OF BENSON AND NELSON
*1903 FARGO AREA
*1902 GRAND FORKS AREA
*1903 JAMESTOWN AREA
*1914 LA MOURE
1971 LA MOURE AND PARTS OF JAMES RIVER VALLEY
*1921 MCHENRY
1942 MCKENZIE
*1907 MCKENZIE AREA
1979 MCLEAN
1979 MERCER
1951 MORTON
*1907 MORTON AREA
1975 OLIVER
1977 PEMBINA
1978 PIERCE
*1906 RANSOM
*1908 RECONNAISSANCE WESTERN
1977 RENVILLE
*1908 RICHLAND
1975 RICHLAND CO. & SHEYENNE NAT. GRASSLAND AREA
*1917 SARGENT
1964 SARGENT
1978 SLOPE
1968 STARK
*1918 TRAILL
1977 TRAILL
1966 TRI-COUNTY AREA
1972 WALSH
1974 WARD
1970 WELLS
*1906 WILLISTON AREA

OHIO

*1938 ADAMS
1965 ALLEN
1973 ASHTABULA
*1903 ASHTABULA AREA
*1938 ATHENS
*1909 AUGLAIZE
*1927 BELMONT
*1930 BROWN
*1927 BUTLER
1971 CHAMPAIGN
1958 CLARK
*1923 CLERMONT
1975 CLERMONT
*1905 CLEVELAND AREA
1962 CLINTON
1968 COLUMBIANA
*1902 COLUMBUS AREA
*1904 COSHOCTON
1979 CRAWFORD
1969 DELAWARE
1971 ERIE
1960 FAIRFIELD
1973 FAYETTE
*1922 FULTON
*1915 GEAUGA
1978 GREENE
*1915 HAMILTON
1973 HANCOCK
1974 HENRY
1977 HIGHLAND
1955 HURON
*1925 LAKE
1979 LAKE
*1938 LICKING
*1939 LOGAN
1976 LORAIN
*1934 LUCAS
*1917 MAHONING
1971 MAHONING
*1916 MARION
1977 MEDINA
*1906 MEIGS
1979 MERCER
*1916 MIAMI
1978 MIAMI
1974 MONROE
*1900 MONTGOMERY
1976 MONTGOMERY
*1925 MUSKINGUM
*1928 OTTAWA
*1914 PAULDING
1960 PAULDING
*1914 PORTAGE
1978 PORTAGE
1969 PREBLE
*1930 PUTNAM
1974 PUTNAM
*1912 RECONNAISSANCE OF STATE OF OHIO
1975 RICHLAND
1967 ROSS
*1917 SANDUSKY
*1940 SCIOTO
*1913 STARK
1971 STARK
1974 SUMMIT
*1902 TOLEDO AREA
*1914 TRUMBULL
1954 TUSCARAWAS
1975 UNION
1972 VAN WERT
*1938 VINTON
1973 WARREN
*1926 WASHINGTON
1977 WASHINGTON
*1905 WESTERVILLE AREA
1979 WILLIAMS
1966 WOOD
*1904 WOOSTER AREA

OKLAHOMA

1965 ADAIR
*1939 ALFALFA
1975 ALFALFA
1979 ATOKA
1962 BEAVER
1968 BLAINE
*1914 BRYAN
1978 BRYAN
1973 CADDO
*1917 CANADIAN
1976 CANADIAN
*1938 CARTER
1979 CARTER
1970 CHEROKEE AND DELAWARE
*1943 CHOCTAW
1979 CHOCTAW
1960 CIMARRON
1954 CLEVELAND
1974 COAL
1967 COMANCHE
1963 COTTON
*1931 CRAIG
1973 CRAIG
1959 CREEK
1978 CUSTER
*1963 DEWEY
1966 ELLIS
*1939 GARFIELD
1967 GARFIELD
1978 GRADY
*1931 GRANT
*1937 GREER
1967 GREER
1960 HARPER
1975 HASKELL
1968 HUGHES
1961 JACKSON
1973 JEFFERSON
1977 JOHNSTON
*1915 KAY
1967 KAY
*1962 KINGFISHER
*1931 KIOWA
1979 KIOWA
*1931 LE FLORE
1970 LINCOLN
1960 LOGAN
1966 LOVE
*1940 MAJOR
1969 MAJOR
*1937 MAYES
1975 MAYES
1979 MCCLAIN
1974 MCCURTAIN
*1938 MCINTOSH
*1939 MURRAY
*1913 MUSKOGEE
1956 NOBLE
1979 NOWATA
*1952 OKFUSKEE
*1906 OKLAHOMA
1969 OKLAHOMA
1968 OKMULGEE
1979 OSAGE
*1964 OTTAWA
*1959 PAWNEE
*1916 PAYNE
*1937 PITTSBURG
1971 PITTSBURG
*1941 PONTOTOC
1973 PONTOTOC
1977 POTTAWATOMIE

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1979 PUSHMATAHA
*1914 ROGER MILLS
*1963 ROGER MILLS
*1966 ROGERS
1979 SEMINOLE
1970 SEQUOYAH
1964 STEPHENS
*1939 TEXAS
1961 TEXAS
*1930 TILLMAN
1974 TILLMAN
*1906 TISHOMINGO AREA
*1942 TULSA
1977 TULSA
1976 WAGONER
1968 WASHINGTON
*1941 WASHITA
1979 WASHITA
1939 WOODS
*1939 WOODWARD
*1963 WOODWARD

OREGON

1973 ALSEA AREA
1949 ASTORIA AREA
1954 BAKER AREA
*1903 BAKER CITY AREA
1920 BENTON
1975 BENTON
*1921 CLACKAMAS
*1929 COLUMBIA
1970 CURRY AREA
1958 DESCHUTES AREA
1925 EUGENE AREA
1926 GRANDE RONDE VALLEY AREA
*1912 HOOD RIVER-WHITE SALMON RIVER AREA
1919 JOSEPHINE
*1908 KLAMATH RECLAMATION PROJECT
1924 LINN
*1927 MARION
1972 MARION
*1909 MARSHFIELD AREA
*1911 MEDFORD AREA
*1919 MULTNOMAH
1922 POLK
1966 PRINEVILLE AREA
*1903 SALEM AREA
1964 SHERMAN
*1973 SOUTH UMPQUA AREA
1964 TILLAMOOK AREA
1975 TROUT CREEK-SHANIKO AREA
1948 UMATILLA AREA
*1919 WASHINGTON
*1917 YAMHILL AREA
1974 YAMHILL AREA

PENNSYLVANIA

*1904 ADAMS
1967 ADAMS
*1939 ARMSTRONG
1977 ARMSTRONG
*1911 BEDFORD
*1909 BERKS
1970 BERKS
*1915 BLAIR
*1911 BRADFORD
*1946 BUCKS
1975 BUCKS AND PHILADELPHIA
*1915 CAMBRIA
1962 CARBON
*1907 CENTRE
*1905 CHESTER
1963 CHESTER AND DELAWARE
1958 CLARION
*1916 CLEARFIELD
1966 CLINTON
1967 COLUMBIA
*1954 CRAWFORD
1979 CRAWFORD
1972 DAUPHIN
*1910 ERIE
1960 ERIE
1973 FAYETTE
*1938 FRANKLIN
1975 FRANKLIN
1969 FULTON
*1921 GREENE
*1944 HUNTINGDON
1978 HUNTINGDON
*1931 INDIANA
1968 INDIANA
1964 JEFFERSON
*1907 JOHNSTOWN AREA
*1914 LANCASTER
1959 LANCASTER
*1900 LANCASTER AREA
*1901 LEBANON AREA
*1912 LEHIGH
1963 LEHIGH
*1903 LOCKHAVEN AREA
*1923 LYCOMING
*1917 MERCER
1971 MERCER
*1905 MONTGOMERY
1967 MONTGOMERY
1955 MONTOUR AND NORTHUMBERLAND
1974 NORTHAMPTON
1969 PIKE
1958 POTTER
*1908 RECONNAISSANCE NORTHWESTERN
*1909 RECONNAISSANCE SOUTHWESTERN
*1910 RECONNAISSANCE SOUTH CENTRAL
*1911 RECONNAISSANCE NORTHEASTERN
*1912 RECONNAISSANCE SOUTHEASTERN
1973 SUSQUEHANNA
*1929 TIOGA
*1946 UNION
1975 VENANGO
*1910 WASHINGTON
*1938 WAYNE
1968 WESTMORELAND
*1929 WYOMING
*1912 YORK
1963 YORK

PUERTO RICO

*1902 ARECIBO TO PONCE
1977 HUMACAO AREA
1965 LAJAS VALLEY AREA
1975 MAYAGUEZE AREA OF WESTERN PUERTO RICO
1979 PONCE AREA
1942 PUERTO RICO
1978 SAN JUAN AREA

RHODE ISLAND

*1939 KENT AND WASHINGTON
*1942 NEWPORT AND BRISTOL
*1943 PROVIDENCE
*1904 RECONNAISSANCE OF RHODE ISLAND

SOUTH CAROLINA

1937 ABBEVILLE
*1902 ABBEVILLE AREA
*1909 ANDERSON
1979 ANDERSON
*1913 BAMBERG
1966 BAMBERG
*1912 BARNWELL
1977 BARNWELL
*1916 BERKELEY
*1963 CALHOUN
*1903 CAMPOBELLO AREA
1971 CHARLESTON
*1904 CHARLESTON AREA
*1905 CHEROKEE
1962 CHEROKEE
*1912 CHESTER
*1914 CHESTERFIELD
*1910 CLARENDON
1976 CLARENDON
*1909 CONWAY AREA
1960 DARLINGTON
*1902 DARLINGTON AREA
*1931 DILLON
1978 DILLON
*1915 DORCHESTER
*1938 EDGEFIELD
*1911 FAIRFIELD
*1914 FLORENCE
1974 FLORENCE AND SUMTER
*1911 GEORGETOWN
*1921 GREENVILLE
1975 GREENVILLE
*1929 GREENWOOD
*1915 HAMPTON
*1918 HORRY
*1919 KERSHAW
*1904 LANCASTER
1973 LANCASTER
1975 LAURENS AND UNION
*1907 LEE
1963 LEE
*1922 LEXINGTON
1976 LEXINGTON
*1917 MARLBORO
*1965 MARLBORO
*1918 NEWBERRY
1960 NEWBERRY
*1907 OCONEE
1963 OCONEE
*1913 ORANGEBURG
*1904 ORANGEBURG AREA
1943 PICKENS
1972 PICKENS
*1916 RICHLAND
1978 RICHLAND
*1909 SALUDA
1962 SALUDA
*1921 SPARTANBURG
1968 SPARTANBURG
*1907 SUMTER
1943 SUMTER
*1913 UNION
*1928 WILLIAMSBURG
*1905 YORK
1965 YORK

SOUTH DAKOTA

*1920 BEADLE
1979 BEADLE
*1907 BELLEFOURCHE AREA
1971 BENNETT
1959 BROOKINGS
*1903 BROOKINGS AREA
*1925 BROWN
1976 BUTTE
1979 CAMPBELL
1966 CODINGTON

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1977 EDMUNDS
1974 DAVISON
1979 DEWEY
*1923 DOUGLAS
*1922 GRANT
1979 GRANT
1963 HAND
1978 HANSON AND HUTCHINSON
1975 HUGHES
*1925 HYDE
1973 LAKE
1979 LAWRENCE
1976 LINCOLN
1975 MARSHALL
*1921 MCCOOK
1978 MEADE, SOUTHERN PART
1975 MELLETTE
1964 MINNEHAHA
*1926 MOODY
*1909 RECONNAISSANCE WESTERN
SOUTH DAKOTA
1977 ROBERTS
1971 SHANNON
1975 SULLY
1974 TODD
1979 TRIPP
*1921 UNION
1978 UNION
*1923 WALWORTH
1969 WASHABAUGH
1979 YANKTON

TENNESSEE

1947 BEDFORD
1953 BENTON
1959 BLOUNT
1958 BRADLEY
1953 CARTER
1948 CLAIBORNE
1955 COCKE
*1908 COFFEE
1959 COFFEE
1950 CUMBERLAND
*1903 DAVIDSON
1955 DECATUR
1972 DEKALB
*1923 DICKSON
1965 DYER
1964 FAYETTE
1958 FRANKLIN
*1907 GILES
1968 GILES
*1906 GRAINGER
1948 GRAINGER
1958 GREENE
*1904 GREENEVILLE AREA
1946 HAMBLEN
1947 HAMILTON
*1926 HARDIN
1963 HARDIN
1979 HAWKINS AND HANCOCK
*1905 HENDERSON
1960 HENDERSON
*1922 HENRY
1958 HENRY
1959 HOUSTON
1946 HUMPHREYS
*1913 JACKSON
1941 JEFFERSON
1956 JOHNSON
1955 KNOX
1969 LAKE
*1904 LAWRENCE
1959 LAWRENCE
1946 LINCOLN
1961 LOUDON
*1906 MADISON
1978 MADISON
1958 MARION
*1923 MAURY
1959 MAURY
1957 MCMINN
*1919 MEIGS
1974 MEIGS
*1901 MONTGOMERY
1975 MONTGOMERY
1953 NORRIS AREA
1973 OBION
*1908 OVERTON
*1953 PERRY
*1903 PIKEVILLE AREA
*1912 PUTNAM
1963 PUTNAM
1948 RHEA
1942 ROANE
*1912 ROBERTSON
1968 ROBERTSON
1977 RUTHERFORD
1956 SEVIER
*1916 SHELBY
1970 SHELBY
1953 STEWART
1953 SULLIVAN
*1909 SUMNER
1967 WARREN
1958 WASHINGTON
1964 WILLIAMSON

TEXAS

*1904 ANDERSON
1975 ANDERSON
1974 ANDREWS
*1912 ARCHER
*1965 ARMSTRONG
*1904 AUSTIN AREA
1963 BAILEY
1977 BANDERA
*1907 BASTROP
1979 BASTROP
1976 BAYLOR
*1938 BEE
*1916 BELL
1977 BELL
*1966 BEXAR
1979 BLANCO AND BURNET
1975 BORDEN
*1918 BOWIE
*1902 BRAZORIA AREA
*1914 BRAZOS
*1958 BRAZOS
1977 BRISCOE
*1948 BROWN
*1907 BROWNSVILLE AREA
1978 CALDWELL
1978 CALHOUN
*1941 CAMERON
1977 CAMERON
*1908 CAMP
*1962 CARSON
*1937 CASS
1974 CASTRO
1976 CHAMBERS
*1959 CHEROKEE
*1963 CHILDRESS
*1964 COCHRAN
1974 COKE
*1922 COLEMAN
1974 COLEMAN
*1920 COLLIN
1969 COLLIN
1973 COLLINGSWORTH
1977 COMANCHE
1979 COOKE
*1907 COOPER AREA
*1908 CORPUS CHRISTI AREA
1974 COTTLE
*1966 CROSBY
1975 DALLAM
*1920 DALLAS
1960 DAWSON
1968 DEAF SMITH
*1918 DENTON
1978 DE WITT
*1922 DICKENS
1970 DICKENS
*1943 DIMMIT
*1916 EASTLAND
1977 EASTLAND
1978 ECTOR AND CRANE
1971 EL PASO
*1910 ELLIS
1964 ELLIS
*1920 ERATH
1973 ERATH
*1932 FALLS
1978 FALLS
*1946 FANNIN
*1966 FISHER
1978 FLOYD
*1964 FOARD
*1960 FORT BEND
*1908 FRANKLIN
*1918 FREESTONE
*1929 FRIO
*1965 GAINES
*1930 GALVESTON
1975 GARZA
1975 GILLESPIE
1977 GLASSCOCK
1966 GRAY
*1909 GRAYSON
1977 GUADALUPE
1974 HALE
1967 HALL
*1960 HANSFORD
*1932 HARDEMAN
1972 HARDEMAN
*1922 HARRIS
1976 HARRIS
*1912 HARRISON
1977 HARTLEY
1961 HASKELL
1974 HEMPHILL
*1906 HENDERSON
*1923 HENDERSON
*1925 HIDALGO
1978 HILL
1965 HOCKLEY
1978 HOOD AND SOMERVELL
1977 HOPKINS AND RAINS
*1905 HOUSTON
1969 HOWARD
*1939 HUNT
1976 HUTCHINSON
*1903 JACKSONVILLE AREA
1977 JEFF DAVIS
*1913 JEFFERSON
1965 JEFFERSON
1974 JIM HOGG
1979 JIM WELLS
1972 JONES
*1940 KAUFMAN
1977 KAUFMAN AND ROCKWALL
1973 KENT
1967 KINNEY
1979 KNOX
1979 LAMAR AND DELTA
*1962 LAMB
*1906 LAREDO AREA
*1905 LAVACA
*1905 LEE
1975 LIPSCOMB

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*1917 LUBBOCK
1979 LUBBOCK
*1903 LUFKIN AREA
*1959 LYNN
1975 MARTIN
*1942 MAVERICK
1977 MAVERICK
1974 MCCULLOCH
1958 MCLENNAN
1977 MEDINA
*1967 MENARD
*1928 MIDLAND
1973 MIDLAND
*1925 MILAM
1969 MITCHELL
1978 MONTAGUE
1972 MONTGOMERY
1975 MOORE
*1909 MORRIS
1977 MOTLEY
*1925 NACOGDOCHES
*1903 NACOGDOCHES AREA
*1926 NAVARRO
1975 NAVARRO
1965 NUECES
1973 OCHILTREE
1975 PANOLA
*1903 PARIS AREA
1977 PARKER
1978 PARMER
*1930 POLK
*1929 POTTER
*1930 RANDALL
1970 RANDALL
*1910 RECONNAISSANCE CENTRAL GULF COAST
*1919 RECONNAISSANCE NORTHWEST
*1910 RECONNAISSANCE PANHANDLE
*1909 RECONNAISSANCE SOUTH
*1913 RECONNAISSANCE SOUTH CENTRAL
*1911 RECONNAISSANCE SOUTHWEST
*1928 RECONNAISSANCE TRANS-PECOS AREA
*1922 RECONNAISSANCE WEST CENTRAL
*1919 RED RIVER
1977 RED RIVER
*1922 REEVES
*1907 ROBERTSON
*1923 ROCKWALL
1970 RUNNELS
*1904 SAN ANTONIO AREA
*1906 SAN MARCOS AREA
1979 SAN PATRICIO AND ARANSAS
*1916 SAN SABA
*1931 SCURRY
1973 SCURRY
1975 SHERMAN
*1915 SMITH
1972 STARR
1977 STERLING
1975 STONEWALL
1968 SUTTON
1974 SWISHER
*1920 TARRANT
*1915 TAYLOR
1976 TAYLOR
1974 TERRELL
*1962 TERRY
*1931 THE SOILS OF TEXAS
*1909 TITUS
1976 TOM GREEN
1974 TRAVIS
1976 UVALDE
*1928 VAN ZANDT
*1902 VERNON AREA
*1927 VICTORIA
*1905 WACO AREA
1979 WALKER
1975 WARD
*1913 WASHINGTON
1974 WHARTON
*1932 WHEELER
1975 WHEELER
*1962 WIBARGER
*1924 WICHITA
1977 WICHITA
*1926 WILLACY
*1938 WILLIAMSON
*1901 WILLIS AREA
*1907 WILSON
1977 WILSON
*1903 WOODVILLE AREA
*1964 YOAKUM
*1940 ZAVALA

UTAH

*1920 ASHLEY VALLEY AREA
*1904 BEAR RIVER AREA
1976 BEAVER-COVE FORT AREA
1960 BERYL-ENTERPRISE AREA
1975 BOX ELDER
*1913 CACHE VALLEY AREA
1974 CACHE VALLEY AREA
1970 CARBON-EMERY AREA
1968 DAVIS-WEBER
*1919 DELTA AREA
1977 DELTA AREA
*1959 EAST MILLARD AREA
1976 HEBER VALLEY AREA
1976 MEADOW VALLEY AREA
*1939 PRICE AREA
*1903 PROVO AREA
*1899 RECONNAISSANCE SANPETE, CACHE, AND UTAH
*1958 RICHFIELD AREA
*1959 ROOSEVELT-DUCHESNE AREA
*1946 SALT LAKE AREA
1974 SALT LAKE AREA
*1899 SALT LAKE VALLEY AREA
1962 SAN JUAN AREA
*1900 SEVIER VALLEY AREA
*1921 UINTA RIVER VALLEY AREA
1972 UTAH (CENTRAL PART)
*1942 VIRGIN RIVER VALLEY AREA
1977 WASHINGTON AREA
*1900 WEBER AREA

VERMONT

1971 ADDISON
1974 CHITTENDEN
1979 FRANKLIN
*1959 GRAND ISLE
1978 ORANGE
*1937 RECONNAISSANCE OF ENTIRE STATE
*1904 VERGENNES AREA
*1916 WINDSOR

VIRGINIA

*1917 ACCOMACK AND NORTHAMPTON
*1940 ALBEMARLE
*1902 ALBEMARLE AREA
*1904 APPOMATTOX
*1937 AUGUSTA
1979 AUGUSTA
*1901 BEDFORD AREA
1954 BLAND
*1909 CAMPBELL
1977 CAMPBELL AND CITY OF LYNCHBURG
1967 CARROLL
1974 CHARLOTTE
*1906 CHESTERFIELD
1978 CHESTERFIELD
*1952 CULPEPER
1963 FAIRFAX
*1915 FAIRFAX AND ALEXANDRIA
1956 FAUQUIER
1958 FLUVANNA
*1914 FREDERICK
*1930 GRAYSON
*1938 HALIFAX
*1905 HANOVER
*1914 HENRICO
1975 HENRICO
*1941 ISLE OF WIGHT
1953 LEE
*1903 LEESBURG AREA
1960 LOUDOUN
*1905 LOUISA
1976 LOUISA
1975 MADISON
1962 MATHEWS
1956 MECKLENBURG
*1907 MONTGOMERY
*1932 NANSEMOND
*1903 NORFOLK AREA
1959 NORFOLK AREA
1963 NORTHUMBERLAND AND LANCASTER
1960 NOTTOWAY
*1927 ORANGE
1971 ORANGE
*1918 PITTSYLVANIA
1958 PRINCE EDWARD
*1901 PRINCE EDWARD AREA
*1945 PRINCESS ANNE AREA
1961 RAPPAHANNOCK
*1931 ROCKBRIDGE
1945 RUSSELL
1951 SCOTT
*1948 SMYTH
*1937 SOUTHAMPTON
1974 STAFFORD AND KING GEORGE
*1948 TAZEWELL
*1945 WASHINGTON
*1954 WISE
*1905 YORKTOWN AREA

VIRGIN ISLANDS

*1932 RECONNAISSANCE OF ST. CROIX ISLAND
1970 VIRGIN ISLANDS OF THE U.S.

WASHINGTON

1967 ADAMS
*1907 BELLINGHAM
*1916 BENTON
1971 BENTON
1975 CHELAN AREA
1951 CLALLAM
1972 CLARK
1973 COLUMBIA AREA
1974 COWLITZ AREA
*1905 EVERETT AREA
*1914 FRANKLIN
1974 GARFIELD AREA
*1912 HOOD RIVER-WHITE SALMON RIVER AREA
*1905 ISLAND
1958 ISLAND
1975 JEFFERSON AREA
1952 KING
1973 KING AREA
*1939 KITSAP
*1945 KITTITAS

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1954 LEWIS
1960 MASON
1979 NORTH FERRY
1955 PIERCE
1979 PIERCE AREA
*1911 QUINCY AREA
*1911 RECONNAISSANCE SOUTHWESTERN
1929 RECONNAISSANCE COLUMBIA BASIN AREA
*1909 RECONNAISSANCE EASTERN PART PUGET SOUND BASIN
*1910 RECONNAISSANCE WEST PART OF PUGET SOUND BASIN
1962 SAN JUAN
1960 SKAGIT
1956 SKAMANIA
*1947 SNOHOMISH
*1917 SPOKANE
1968 SPOKANE
*1913 STEVENS
1958 THURSTON
1964 WALLA WALLA
*1902 WALLA WALLA AREA
*1918 WENATCHEE AREA
1953 WHATCOM
1958 YAKIMA
*1901 YAKIMA AREA
1976 YAKIMA INDIAN RESER. (IRRIGATED AREA)

WEST VIRGINIA

1968 BARBOUR
*1917 BARBOUR AND UPSHUR
1966 BERKELEY
*1913 BOONE
*1918 BRAXTON AND CLAY
1974 BROOKE, HANCOCK, AND OHIO
*1910 CLARKSBURG AREA
*1919 FAYETTE
1975 FAYETTE AND RALEIGH
*1922 GRANT AND MINERAL
*1941 GREENBRIER
1972 GREENBRIER
*1927 HAMPSHIRE
1978 HAMPSHIRE, MINERAL, AND MORGAN
*1930 HARDY AND PENDLETON
*1911 HUNTINGTON AREA
1961 JACKSON AND MASON
1973 JEFFERSON
*1916 JEFFERSON, BERKELEY, AND MORGAN
*1912 KANAWHA
*1915 LEWIS AND GILMER
*1913 LOGAN AND MINGO
1960 MARSHALL
*1914 MCDOWELL AND WYOMING
*1923 MERCER
*1907 MIDDLEBOURNE AREA
*1925 MONROE
1965 MONROE
*1911 MORGANTOWN AREA
*1920 NICHOLAS
*1908 PARKERSBURG AREA
*1938 POCAHONTAS
*1910 POINT PLEASANT AREA
*1912 PRESTON
*1959 PRESTON
*1914 RALEIGH
*1931 RANDOLPH
*1909 SPENCER AREA
*1924 SUMMERS
*1921 TUCKER
*1967 TUCKER-RANDOLPH
*1905 UPSHUR
*1918 WEBSTER
*1906 WHEELING AREA
1970 WOOD AND WIRT

WISCONSIN

*1920 ADAMS
1958 BARRON
*1910 BAYFIELD
1961 BAYFIELD
*1929 BROWN
1974 BROWN
*1913 BUFFALO
1962 BUFFALO
*1925 CALUMET
*1911 COLUMBIA
1978 COLUMBIA
*1930 CRAWFORD
1961 CRAWFORD
*1913 DANE
1978 DANE
*1916 DOOR
1978 DOOR
1975 DUNN
1977 EAU CLAIRE
*1911 FOND DU LAC
1973 FOND DU LAC
1961 GRANT
*1922 GREEN
1974 GREEN
*1922 GREEN LAKE
1977 GREEN LAKE
*1910 IOWA
1962 IOWA
*1918 JACKSON
*1902 JANESVILLE AREA
*1912 JEFFERSON
1979 JEFFERSON
*1911 JUNEAU
*1919 KENOSHA AND RACINE
1970 KENOSHA AND RACINE
*1911 KEWAUNEE
*1911 LA CROSSE
1960 LA CROSSE
1966 LAFAYETTE
*1926 MANITOWOC
1975 MARQUETTE
*1916 MILWAUKEE
1971 MILWAUKEE AND WAUKESHA
*1923 MONROE
*1918 OUTAGAMIE
1978 OUTAGAMIE
1970 OZAUKEE
1964 PEPIN
*1923 PIERCE
1968 PIERCE
1979 POLK
*1905 PORTAGE
*1915 PORTAGE
1978 PORTAGE
*1906 RACINE
*1913 RECONNAISSANCE NORTHEASTERN
*1909 RECONNAISSANCE MARINETTE
*1914 RECONNAISSANCE NORTH PART OF NORTHWESTERN
*1914 RECONNAISSANCE NORTH PART OF NORTH CENTRAL
*1915 RECONNAISSANCE SOUTH PART OF NORTH CENTRAL
1959 RICHLAND
*1917 ROCK
1974 ROCK
*1925 SAUK
*1924 SHEBOYGAN
1978 SHEBOYGAN
1978 ST. CROIX
*1904 SUPERIOR AREA
*1927 TREMPEALEAU
1977 TREMPEALEAU
*1928 VERNON
1969 VERNON
*1903 VIROQUA AREA
*1920 WALWORTH
1971 WALWORTH
1971 WASHINGTON
*1921 WASHINGTON AND OZAUKEE
*1910 WAUKESHA
*1917 WAUPACA
*1909 WAUSHARA
*1927 WINNEBAGO
*1915 WOOD
1977 WOOD

WYOMING

*1928 BASIN AREA
*1955 CAMPBELL
*1917 FORT LARAMIE AREA
1971 GOSHEN (SOUTHERN PART)
*1939 JOHNSON
1975 JOHNSON
*1903 LARAMIE AREA
1974 RIVERTON AREA
*1939 SHERIDAN
*1927 SHOSHONE AREA
1976 STAR VALLEY AREA
1969 TETON AREA IDAHO-WYOMING
*1940 UINTA
*1926 WHEATLAND AREA

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June 1980

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ALLENTOWN DISTRICT OFFICE

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WILMINGTON DISTRICT OFFICE

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Charleston, West Virginia 25301
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WHEELING FIELD STATION

US Department of Labor - OSHA
US Courthouse Federal Building
Chapline & 12th Streets Room 411
Wheeling, West Virginia 26003
Comm. Phone: 304-232-8044
FTS Phone: 923-1062

ELKINS FIELD STATION

US Department of Labor - OSHA
Federal Building & USPO Room 317
PO Box 1427
Elkins, West Virginia 26241
Comm. Phone: 304-636-6224
FTS Phone: 923-5281

RICHMOND AREA OFFICE

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NORFOLK DISTRICT OFFICE

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200 Granby Mall
Norfolk, Virginia 23510
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FALLS CHURCH FIELD STATION

US Department of Labor - OSHA
Falls Church Office Building Room 111
900 South Washington Street
Falls Church, Virginia 22046
Comm. Phone: 703-557-1330
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ROANOKE FIELD STATION

US Department of Labor - OSHA
210 Franklin Road, SW Room 443
PO Box 2828
Roanoke, Virginia 24011
Comm. Phone: 703-982-6342
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WASHINGTON, DC AREA OFICE

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LaVista Perimeter Office Park
Tucker, Georgia 30084
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FTS Phone: 242-4767

BIRMINGHAM AREA OFFICE

Frank P. Flanagan, Area Director
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Todd Mall
2047 Canyon Road
Birmingham, Alabama 35216
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FTS Phone: 229-1541

FLORENCE FIELD STATION

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ANNISTON FIELD STATION

Roy M. Hirano
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HUNTSVILLE FIELD STATION

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TUPELO FIELD STATION

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MACON AREA OFFICE

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ALBANY FIELD STATION

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US Department of Labor - OSHA
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MOBILE AREA OFFICE

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Mobile, Alabama 36602
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DOTHAN FIELD STATION

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US Department of Labor - OSHA
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Dothan, Alabama 36303
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MONTGOMERY FIELD STATION

John Hall
US Department of Labor - OSHA
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NASHVILLE AREA OFFICE

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ORLANDO FIELD STATION

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US Department of Labor - OSHA
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CLEVELAND AREA OFFICE

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AKRON AREA OFFICE

US Department of Labor - OSHA
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Akron, Ohio 44308
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FTS Phone: 292-5871

DETROIT AREA OFFICE

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US Department of Labor - OSHA
USPO & Courthouse Room 423
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Indianapolis, Indiana 46204
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FTS Phone: 331-7290

GARY DISTRICT OFFICE

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FTS Phone: NONE

FORT WAYNE DISTRICT OFFICE

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USPO Building
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Fort Wayne, Indiana 46802
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FTS Phone: 333-9170

EVANSVILLE DISTRICT OFFICE

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Department of Labor - OSHA
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EAU CLAIRE DISTRICT OFFICE

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FTS Phone: 784-9231

SUPERIOR FIELD STATION

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Superior, Wisconsin 54880
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FTS Phone: NONE

DALLAS-REGION VI (ARKANSAS, LOUISIANA, NEW MEXICO, OKLAHOMA AND TEXAS)

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TYLER AREA OFFICE

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FTS Phone: 749-6064

ALBUQUERQUE AREA OFFICE

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Albuquerque, New Mexico 87102
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FTS Phone: 474-3411

AUSTIN AREA OFFICE

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US Department of Labor - OSHA
AmericanBank Tower, Suite 310
211 West 6th Street
Austin, Texas 78701
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SAN ANTONIO DISTRICT OFFICE

US Department of Labor - OSHA
1015 Jackson Keller Road Room 215
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FTS Phone: 730-5410

BATON ROUGE AREA OFFICE

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CORPUS CHRISTI DISTRICT OFFICE

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BEAUMONT DISTRICT OFFICE

US Department of Labor - OSHA
Professional Building Suite 300
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Beaumont, Texas 77702
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FTS Phone: 527-2259

CLEAR LAKE CITY AREA OFFICE

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LITTLE ROCK AREA OFFICE

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LUBBOCK AREA OFFICE

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Lubbock, Texas 79401
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FTS Phone: 738-7681

EL PASO FIELD STATION

Carlos Gonzales
US Department of Labor - OSHA
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El Paso, Texas 79925
Comm. Phone: 915-543-7828
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NEW ORLEANS AREA OFFICE

John S. Svalina, Area Director
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600 South Street Room 337
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FTS Phone: 682-6166 & 682-2451

TULSA AREA OFFICE

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US Department of Labor - OSHA
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Tulsa, Oklahoma 74127
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FTS Phone: 736-7676

OKLAHOMA CITY AREA OFFICE

William W. White, Jr., Area Director
US Department of Labor - OSHA
50 Penn Place Suite 408
Oklahoma City, Oklahoma 73118
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FTS Phone: 736-5351

KANSAS CITY-REGION VII (IOWA, KANSAS, MISSOURI AND NEBRASKA)

KANSAS CITY REGIONAL OFFICE

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FTS Phone: 758-5861

KANSAS CITY AREA OFFICE

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DES MOINES AREA OFFICE

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NORTH PLATTE DISTRICT OFFICE

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ST. LOUIS AREA OFFICE

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Bismarck, North Dakota 58501
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FTS Phone: 783-4521

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Denver, Colorado 80204
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GRAND JUNCTION DISTRICT OFFICE

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US Department of Labor - OSHA
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FTS Phone: 322-0340

SALT LAKE CITY AREA OFFICE

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US Department of Labor - OSHA
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Salt Lake City, Utah 84101
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SIOUX FALLS AREA OFFICE

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Sioux Falls, South Dakota 57102
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FTS Phone: 782-4425

SAN FRANCISCO-REGION IX (AMERICAN SOMOA, ARIZONA, CALIFORNIA, GUAM, HAWAII, NEVADA, TRUST TERRITORY OF THE PACIFIC ISLANDS)

SAN FRANCISCO REGIONAL OFFICE

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SAN FRANCISCO AREA OFFICE

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FRESNO FIELD STATION

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FTS Phone: 467-5454

SACRAMENTO FIELD STATION

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CARSON CITY AREA OFFICE

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LAS VEGAS FIELD STATION

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US Department of Labor - OSHA
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Las Vegas, Nevada 89101
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HONOLULU AREA OFFICE

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US Department of Labor - OSHA
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LONG BEACH AREA OFFICE

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TUCSON FIELD STATION

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SEATTLE-REGION X (ALASKA, IDAHO, OREGON AND WASHINGTON)

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ANCHORAGE AREA OFFICE

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BOISE AREA OFFICE

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US Department of Labor - OSHA
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Boise, Idaho 83702
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COEUR D'ALENE FIELD STATION

US Department of Labor - OSHA
205 North 4th Street
PO Box 1549
Coeur D'Alene, Idaho 83814
Comm. Phone: 208-667-7491
FTS Phone: 442-9465

LEWISTON FIELD STATION

US Department of Labor - OSHA
1618 Idaho Street
PO Box 1223
Lewiston, Idaho 83501
Comm. Phone: 208-743-2589
FTS Phone: NONE

POCATELLO FIELD STATION

US Department of Labor - OSHA
250 South 4th Street Suite 178
Pocatello, Idaho 83201
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FTS Phone: 554-6855

PORTLAND AREA OFFICE

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Portland, Oregon 97204
Comm. Phone: 503-221-2251
FTS Phone: 423-2251

OSHA TRAINING INSTITUTE

OSHA Training Institute
US Department of Labor
1555 Times Drive
Des Plaines, Illinois 60018
Comm. Phone: 312-297-4810
FTS Phone: 353-2500

CINCINNATI LABORATORY

OSHA Cincinnati Laboratory
USPO Building Room 108
5th & Walnut Streets
Cincinnati, Ohio 45202
Comm. Phone: 513-684-2531
FTS Phone: 684-2531

SALT LAKE CITY LABORATORY

SLC Analytical Laboratory
390 Wakara Way Research Park
Salt Lake City, Utah 84108
Comm. Phone: 801-524-5287
FTS Phone: 588-5287

HEALTH RESPONSE UNIT, SLC

Robert Peterson
Health Response Unit - OSHA
390 Wakara Way
Salt Lake City, Utah 84108
Comm. Phone: 801-524-5896
FTS Phone: 588-5896

A8-i

PART 8

MAP PRODUCTS AND SOURCES

TABLE 1. Map products and sources

[Addresses of Federal, State, and other agencies identified by acronyms in this table begin on page 247.]

Products	Producing agency	Available from
Aeronautical charts	NOS	NOS
Boundary information:		
United States and Canada	IBC	IBC
United States and Mexico	IBWC	IBWC
Boundary and annexation surveys of incorporated places with 2,500 or more inhabitants	BC	GPO
Civil subdivisions and reservations	BLM	BLM
State/Federal	DOS	DOS
Census data (social and economic)	BC	GPO
Climatic maps	NWS	NWS
Earthquake hazard maps	USGS	USGS
Federal property maps:		
Bureau of Reclamation	BR	BR
Fish and Wildlife Service	FWS	FWS
National Aeronautics and Space Administration	NASA	NASA
National forests	FS	FS
National Park Service	NPS	NPS
Military reservations:		
Air Force	USAF	USAF
Army	USA	USA
Coast Guard	USCG	USCG
Marines	USMC	USMC
Navy	USN	USN
State maps of lands administered by Bureau of Land Management	BLM	BLM
U.S. maps of lands administered by Bureau of Land Management	BLM	BLM
Flood-plain maps	DRBC	DRBC
	FIA	FIA
	MRC	MRC
	NOS	FIA
	SCS	SCS
	USCE	USCE
	USGS	USGS
Geodetic control data	NOS	NOS
	USCE	USCE
	USGS	NOS/ NCIC
Geologic maps:		
Coal investigations	USGS	USGS
General geologic	SGA	SGA
	USGS	USGS
Geophysical investigations	NOAA	EDS
	NOAA	ERL
	USGS	USGS
Mineral investigations	USGS	USGS
Mines	BM	BM
Oil and gas investigations	USGS	USGS
Geographic maps:	NOS	NOS
Land use	USGS	USGS
Highway maps:		
Indian lands	BIA	BIA
Federal lands	FHWA	FHWA
Federally funded roads	FHWA	GPO
Federal primary and secondary	FHWA	GPO
Interstate	FHWA	FHWA
Federal highway maps of the U.S.	FHWA	GPO
Historical maps and charts	LC	LC
	All Federal agencies	NARS
Hydrographic charts and bathymetric maps:	NOS	NOS
	USCE	USCE
	USGS	USGS
Hydrographic surveys	NOS	NOS
	USGS	USGS
Nautical charts	NOS	NOS
	USCE	USCE
Navigable waterways maps	USCE	USCE
River and stream surveys	MRC	MRC
River basin/watershed studies	ERC	ERC
	SCS	SCS
	USGS	USGS
River surveys	BR	BR
	USGS	USGS
Wildlife and scenic river jurisdiction	BLM	BLM
Hydrologic investigations atlases	USGS	USGS
Indian reservations:		
Land surveys	BIA	GPO
U.S. maps of Indian lands	BIA	GPO
Land plats	BLM	BLM
	BLM	NARS
	NPS	NPS
	USCE	USCE
National Atlas of the U.S.	USGS	USGS
Photographic products:		
Aerial photographs	ASCS	ASCS
	BLM	BLM
	BLM	EDC
	BPA	BPA
	DMA	DMA
	NASA	EDC
	FHWA	FHWA
	FS	EDC
	FS	NCIC
	FWS	EDC
	FWS	NCIC
	NOS	NOS
	NPS	NPS
	SCS	SCS
	USCE	USCE
	FS	FS
	USGS	NCIC/ EDC
Orthophotomaps	BIA	BIA
	NOS	NOS
	USGS	USGS
Space imagery:		
Landsat (ERTS)	NASA	ASCS
	NASA	EDC
	NASA	EDS
NASA manned spacecraft	NASA	EDC
Nimbus	NWS	NWS
Skylab	NASA	ASCS
	NASA	EDC
Tiros	NWS	NWS
Recreation maps	BLM	BLM
	HCRC	HCRC

TABLE 1. Map products and sources *(continued)*

Products	*Producing agency*	*Available from*
Seismicity maps and charts	ERL USGS	**ERL** **USGS**
Soils	SCS	**SCS**
Soils—substation quality	BPA	**BPA**
Topographic maps	USGS MRC NASA	**USGS** **MRC** **NASA**
Utilities:		
Ground conductivity maps of the U.S.	FCC	**GPO**
Principal electric-facilities maps of the U.S.	ERC	**GPO**
Principal natural-gas-pipelines maps of the U.S.	ERC	**GPO**
Water resources development data	USGS	**USGS**
Miscellaneous data:		
Clinometric (slope) maps	USGS	**USGS**
Gravity survey charts	EDS NOS USGS	**EDS** **NOS** **USGS**
Income distribution maps	BC	**GPO**
Isogonic charts	USGS	**USGS**
Isomagnetic charts	NOS	**NOS**
Magnetic charts	EDS	**EDS**
National science trail maps	SCS	**SCS**
State indexes of fish hatcheries and national wildlife refuges	FWS	**FWS**
Storm evacuation maps	NOS	**NOS**
Tree danger (to powerlines) detection maps	BPA	**BPA**
U.S. location maps of fish hatcheries and national wildlife refuges	FWS	**FWS**

ADDRESSES OF AGENCIES

[*See table 1, p. 18–19, for map products available from these agencies.*]

Agricultural Stabilization and Conservation Service (ASCS)
Aerial Photography Field Office
Agricultural Stabilization and Conservation Service
Department of Agriculture
(2222 West, 2300 South)
P.O. Box 30010
Salt Lake City, Utah 84125

Bonneville Power Administration (BPA)
Bonneville Power Administration
Department of Energy
(1002 NE. Holladay Street)
P.O. Box 3621
Portland, Oreg. 97208

Bureau of the Census (BC)
Users Service Staff
Data Users Services Division
Bureau of the Census
Department of Commerce
Washington, D.C. 20233

Bureau of Indian Affairs (BIA)
Bureau of Indian Affairs
Department of the Interior
18th and C Streets, NW.
Washington, D.C. 20240

Bureau of Land Management (BLM)
Bureau of Land Management
Department of the Interior
18th and C Streets, NW.
Washington, D.C. 20240

Bureau of Mines (BM)
Environmental Affairs Field Office
Bureau of Mines
Department of the Interior
Room 3323
Penn Place
20 North Pennsylvania Avenue
Wilkes-Barre, Pa. 18701

Mine Map Repository
Bureau of Mines
Department of the Interior
Building 20
Denver Federal Center
Denver, Colo. 80225

Mine Map Repository
Bureau of Mines
Department of the Interior
4800 Forbes Avenue
Pittsburgh Pa. 15213

Bureau of Reclamation (BR)
Chief, Publications and Photography Branch
General Services Division
Bureau of Reclamation
7442 Interior Building
18th and C Streets, NW.
Washington, D.C. 20240

Defense Mapping Agency (DMA)
Defense Mapping Agency
Building 56
U.S. Naval Observatory
Washington, D.C. 20305

Delaware River Basin Commission (DRBC)
Executive Director
Delaware River Basin Commission
(25 State Police Drive)
Post Office Box 7360
West Trenton, N.J. 08628

Department of Energy (DOE)
Public Affairs Director
Department of Energy
1000 Independence Avenue, SW.
Washington, D.C. 20585

Department of State (DOS)
Office of the Geographer
Bureau of Intelligence and Research
Department of State
8742 NS INR/RGE
Washington, D.C. 20520

Environmental Protection Agency (EPA)
Office of Public Awareness
Environmental Protection Agency
401 M Street, SW.
Washington, D.C. 20460

Federal Energy Regulatory Commission (ERC)
Office of Public Information
Federal Energy Regulatory Commission
825 North Capital Street, NE.
Washington, D.C. 20426

Federal Highway Administration (FHWA)
Office of Public Affairs
Federal Highway Administration
Department of Transportation
Room 4208
400 7th Street, SW.
Washington, D.C. 20590

Federal Highway Administration (*continued*)
Aerial Surveys Branch
Highway Design Division
Federal Highway Administration
Department of Transportation
Room 3130A
400 7th Street, SW.
Washington, D.C. 20590

Federal Insurance Administration (FIA)
National Flood Insurance Program
Federal Insurance Administration
Department of Housing and Urban Development
P.O. Box 34294
Bethesda, Md. 20034

Heritage Conservation and Recreation Service (HCRC)
(formerly Bureau of Outdoor Recreation)
Federal Land Aquisition Division
Heritage Conservation and Recreation Service
130 Interior South Building
18th and C Streets, NW.
Washington, D.C. 20240

International Boundary and Water Commission, United States and Mexico (IBWC)
U.S. Commissioner
International Boundary and Water Commission, United States and Mexico
United States Section
(4110 Rio Bravo, Executive Center)
P.O. Box 20003
El Paso, Tex. 79998

International Boundary Commission, United States and Canada (IBC)
U.S. Commissioner
International Boundary Commission, United States and Canada
United States Section
Room 150
425 I Street, NW.
Washington, D.C. 20548

Library of Congress (LC)
Geography and Map Division
Library of Congress
845 S. Pickett Street
Alexandria, Va. 22304

Mississippi River Commission (MRC)
Executive Assistant
Mississippi River Commission
(Mississippi River Commission Building)
U.S. Army Corps of Engineers
P.O. Box 80
Vicksburg, Miss. 39180

National Aeronautics and Space Administration (NASA)
Contact the facility office of the installation concerned.

National Archives and Records Service (NARS)
Cartographic Archives Division
National Archives and Records Service
General Services Administration
Archives Building
Pennsylvania Avenue at 8th Street, NW.
Washington, D.C. 20408

National Oceanic and Atmospheric Administration (NOAA)

Environmental Data Service (EDS)
National Climatic Center
Environmental Data Service
National Oceanic and Atmospheric Administration
Department of Commerce
Federal Building
Asheville, N.C. 28801

Environmental Data Service (*continued*)
National Oceanographic Data Center
Environmental Data Service
National Oceanic and Atmospheric Administration
Department of Commerce
3300 Whitehaven Street, NW.
Washington, D.C. 20235

Environmental Research Laboratories (ERL)
Environmental Research Laboratories
National Oceanic and Atmospheric Administration
Department of Commerce
Boulder, Colo. 80302

National Ocean Survey (NOS)

Aerial photographs and shoreline maps:
Coastal Mapping Division, C3415
National Ocean Survey
National Oceanic and Atmospheric Administration
Department of Commerce
Rockville, Md. 20852

Chart sales:
Washington Science Center 1, C5131
National Oceanic and Atmospheric Administration
Department of Commerce
Rockville, Md. 20852

Charts:
Distribution Division, C44
National Ocean Survey
National Oceanic and Atmospheric Administration
Department of Commerce
Riverdale, Md. 20840

General cartographic information:
Physical Science Services Branch, C513
National Ocean Survey
National Oceanic and Atmospheric Administration
Department of Commerce
Rockville, Md. 20852

Geodetic control data:
National Geodetic Survey (NGS)
National Ocean Survey
National Oceanic and Atmospheric Administration
Department of Commerce
Rockville, Md. 20852

National Weather Service (NWS)
World Weather Building
National Weather Service
National Oceanic and Atmospheric Administration
Department of Commerce
Washington, D.C. 20233

National Park Service (NPS)
Office of Communications
National Park Service
3043 Interior Building
18th and C Streets, NW.
Washington, D.C. 20240

Soil Conservation Service (SCS)
Cartographic Staff
Soil Conservation Service
Department of Agriculture
Federal Building
6505 Belcrest Road
Hyattsville, Md. 20782

STATE GEOLOGIC AGENCIES (SGA)
Contact the State Geologist or
other cognizant official in each State.

Tennessee Valley Authority (TVA)
TVA Map Information & Records Unit
Chattanooga, Tenn. 37401

U.S. Air Force (USAF)
Contact the information officer of the base concerned.

U.S. Army (USA)
Contact the commander of the base concerned.

U.S. Army Corps of Engineers (USCE)
Office of Chief of Engineers
U.S. Army Corps of Engineers
Washington, D.C. 20314

U.S. Coast Guard (USCG)
Oceanographic Unit
U.S. Coast Guard
Building 159E, Washington Navy Yard Annex
Washington, D.C. 20390

U.S. Fish and Wildlife Service (FWS)
Division of Realty
U.S. Fish and Wildlife Service
Department of the Interior
555 Matomic Building
1717 H Street, NW.
Washington, D.C. 20240

U.S. Forest Service (FS)
U.S. Forest Service
Office of Information
Department of Agriculture
P.O. Box 2417
Washington, D.C. 20013

U.S. Geological Survey (USGS)

All cartographic data:

User Services Section
National Cartographic Information Center (NCIC)
U.S. Geological Survey
Department of the Interior
MS 507, National Center
(12201 Sunrise Valley Drive)
Reston, Va. 22092

Photographs and remote sensor imagery:

User Services Unit
EROS Data Center (EDC)
U.S. Geological Survey
Department of the Interior
Sioux Falls, S. Dak. 57198

Maps, aerial photographs, and control data by mail:

Alaska
Distribution Section
U.S. Geological Survey
Department of the Interior
101 12th Avenue
Fairbanks, Alaska 99701

States east of Mississippi River plus Puerto Rico
Branch of Distribution, Eastern Region
Publications Division
U.S. Geological Survey
Department of the Interior
1200 South Eads Street
Arlington, Va. 22202

States west of Mississippi River plus Hawaii, Guam, and American Samoa
Branch of Distribution, Central Region
Publications Division
U.S. Geological Survey
Department of the Interior
MS 306, Box 25286
Denver Federal Center
Denver, Colo. 80225

Commercial dealers are listed on sales indexes which can be obtained from any of the above three offices.

U.S. Government Printing Office (GPO)
Assistant Public Printer
(Superintendent of Documents)
U.S. Government Printing Office
North Capitol and H Streets, NW.
Washington, D.C. 20402

U.S. Marine Corps (USMC)
Contact the commander of the base concerned.

U.S. Navy (USN)
Contact the commander of the base concerned.

APPENDIX B

WELL DRILLING REGULATIONS AND REQUIREMENTS

PARTS

1. WATER WELL INDUSTRY CODES AND LICENSING
2. STATE AGENCIES AND OFFICIALS RESPONSIBLE FOR INDUSTRY CODES AND LICENSING

WATER WELL INDUSTRY CODES & LICENSING

A state-by-state summary of water well drilling codes and licensing of contractors and pump installers.

GROUND WATER AGE recently completed its second annual survey of state agencies responsible for water well drilling codes and the licensing of water well drilling contractors and pump installers. The results, detailed in the following table, show which states have codes, states which license drillers and pump installers, states requiring pitless adapters and those permitting use of PVC pipe.

Asked about implementation of the federal Safe Drinking Water Act, on a state level, officials were vague and indefinite about federal and state coordination and the timetable for their state's response to the Act.

Four states, Connecticut, Illinois, South Dakota and Vermont, report that they require a plumber's license in lieu of a well driller's license.

STATE	WELL DRILLING CODE	LICENSE DRILLERS	LICENSE PUMP INSTALLERS	REQUIRE PITLESS ADAPTERS	PERMIT PVC PIPE
ALABAMA	YES	YES	NO	NO	YES
ALASKA	NO	NO	NO	YES	NA
ARIZONA	YES	YES	YES	NA	YES
ARKANSAS	YES	YES	NO	NO	YES
CALIFORNIA	LC	YES	YES	NO	YES
COLORADO	YES	YES	YES	NO	YES
CONNECTICUT	IP	NO[1]	NO	NO[2]	NA

CODES & LICENSING ▪ CODES & LICENSING ▪ CODES

STATE	WELL DRILLING CODE	LICENSE DRILLERS	LICENSE PUMP INSTALLERS	REQUIRE PITLESS ADAPTERS	PERMIT PVC PIPE
DELAWARE	YES	YES	YES	YES	YES
FLORIDA	LG	YES	NO	LC	YES
GEORGIA	YES	NO	NO	NO	NO
HAWAII	NO	YES	NA	NA	NA
IDAHO	YES	YES	NO	NO	NO
ILLINOIS	YES	YES	YES	NO	YES
INDIANA	NO	NO	NO	NO	YES
IOWA	NO	NO	NO	NO	YES
KANSAS	YES	YES	NO	NO	YES
KENTUCKY	NO	NO	NO	NO	YES
LOUISIANA	YES	NO	NO	NO	YES
MAINE	NO	NO	NO	NO	NA
MARYLAND	YES	YES	YES	YES	YES
MASSACHUSETTS	IP	NO	NO	NO	NA
MICHIGAN	YES	YES	YES	NO	YES
MINNESOTA	YES	YES	NO	NO	NO
MISSISSIPPI	NO	YES	NO	NO	NA
MISSOURI	NO	NO	NO	NO	YES
MONTANA	NO	IP	NO	NO	YES
NEBRASKA	YES	IP	NO	NO	YES
NEVADA	YES	YES	NA	NA	YES
NEW HAMPSHIRE	NO	NO	NO	NO	YES
NEW JERSEY	YES	YES	NO	YES	NO
NEW MEXICO	YES[3]	YES	YES[4]	YES[5]	YES
NEW YORK	IP	IP[6]	NO	NO	YES
NORTH CAROLINA	YES	YES	YES	NO	YES

STATE	WELL DRILLING CODE	LICENSE DRILLERS	LICENSE PUMP INSTALLERS	REQUIRE PITLESS ADAPTERS	PERMIT PVC PIPE
NORTH DAKOTA	YES	YES	NO	NO	YES
OHIO	YES	LC	LC	NO	YES
OKLAHOMA	IP	YES[7]	NO	NO	YES
OREGON	YES	YES	IP	NO	NO
PENNSYLVANIA	NO	YES	NO	NO	YES
RHODE ISLAND	NO	YES	NO	NO	NA
SOUTH CAROLINA	IP	NO	NO	NO	YES
SOUTH DAKOTA	NO	YES	YES	NO	YES
TENNESSEE	YES	YES	YES	YES	YES
TEXAS	YES	YES	NO	NO	YES
UTAH	YES	YES	NO	NA	YES
VERMONT	IP	YES	NO	NO	YES
VIRGINIA	NO	NO	NA	NA	NO
WASHINGTON	YES	YES	NO	NO	YES
WEST VIRGINIA	NO	NO	NO	YES	YES
WISCONSIN	YES	YES	YES	YES[8]	YES[9]
WYOMING	IP	IP	NO	NO	YES
DISTRICT of COLUMBIA	NO	NO	NO	NO	NA
GUAM	YES	YES	NO	NO	NA
PUERTO RICO	IP	IP	NO	NO	NA

Key: NA - no answer; LC - local communities or regions set standards; IP - in process; 1 - registers; 2 - encourages use of pitless adapters; 3 - artesian wells only; 4 - approval of Construction Industry Board; 5 - commercial wells only; 6 - Long Island does license drillers; 7 - commercial irrigation only; 8 - needs Department of Natural Resources approval; 9 - on pump installations only with code requirements.

STATE AGENCIES & OFFICIALS

State agencies and key personnel responsible for water well industry codes and licensing.

ALABAMA

Robert A. Livingston, Alabama Water Well Standards Board, 328 State Office Building, Montgomery, Alabama 36130 — *Code control. Health Department issues licenses.*

ALASKA

Lloyd A. Morley, Chief, Environmental Health Section, Division of Public Health, Department of Health and Social Services, Pouch H, Juneau, Alaska 99811 — *Issues permits for public water supplies.*

ARIZONA

Dr. Ronald Miller, Division of Water Quality Control, Arizona State Health Building, 1740 West Adams Street, Phoenix, Arizona 85007 — *Prepares codes.*

John J. Kayetan, State Registrar of Contractors, 1818 West Adams, Phoenix, Arizona 85007 — *Licenses drilling contractors.*

ARKANSAS

P. D. Huff, Executive Secretary, Committee on Water Well Construction, 3815 West Roosevelt Road, Little Rock, Arkansas 72204 — *Prepares drilling codes and licensing of contractors.*

CALIFORNIA

Ed. A. Ritchie, Well Standards Coordinator, Water Resources Evaluation, Division of Resources Development, Box 388, Sacramento, California 95814 — *Standards control maintained here.*

Roy Boddy, Contractors' State License Board, 1020 "N" Street, Sacramento, California 95814 — *Responsible for licensing.*

COLORADO

Paul Haswell, Water Resources Engineer, Department of Natural Resources, 300 Columbine Building, 1845 Sherman Street, Denver, Colorado 80203 — *Responsible for codes and licensing of contractors and pump installers.*

CONNECTICUT

R. Jarema, Sr., Sanitary Engineer, Environmental Health Services Division, Water Supply Section, State Health Department, 79 Elm Street, Hartford, Connecticut 06115 — *Well Drilling Board responsible for codes and licensing of contractors.*

DELAWARE

Lester F. Meyer, Water Resources Section, Division of Environmental Control, Tatnall Building, Dover, Delaware 19901 — *Codes and licensing.*

FLORIDA

Robert Hall, Department of Environmental Regulation, Certification and Manpower Development, 2562 Executive Center, Circle East, Tallahassee, Florida 32301.

GEORGIA

John B. Fernstrom, Department of Natural Resources, Environmental Protection Division, 270 Washington Street, S.W., Atlanta, Georgia 30334 — *Responsible for implementing rules and regulations for water supply.*

HAWAII

Robert T. Chuck, Department of Land and Natural Resources, Division of Water and Land Development, P. O. Box 373, Honolulu, Hawaii 96809 — *Codes.*

State of Hawaii, Department of Regulatory Agencies, P. O. Box 3469, Honolulu, Hawaii 96801 — *Licensing.*

IDAHO

Kenneth H. Foit, P.E., Supervisor Department of Water Resources, Ground Water Section, 373 W. Franklin, Statehouse, Boise, Idaho 83720 — *Standards, Licensing, Waste Disposal and Geothermal Well Drilling permits.*

ILLINOIS

James Mills, Department of Public Health, Springfield, Illinois 62761 — *Responsible for well drilling codes.*

Ronald E. Stackler, Department of Registration and Education, 628 Adams Street, Springfield, Illinois 62706 — *Licenses well drilling contractors and pump installers.*

INDIANA

Joseph D. Cloud, Director, Department of Natural Resources, Indianapolis, Indiana 46204 — *Licensing of water* *well drilling contractors. Health department is responsible for water well drilling codes.*

IOWA

Kenneth C. Choquette, Director, Health Engineering Division, Department of Health, Lucas State Office Building, Des Moines, Iowa 50319.

KANSAS

Dwight W. Brinkley, Oil Field and Environmental Geology Section, Kansas State Department of Health, Topeka, Kansas 66620 — *Responsible for preparing well drilling codes and licensing.*

KENTUCKY

Charles J. Kelly, c/o Moodys of Dayton, 2206 Frankfort Avenue, Louisville, Kentucky 40206 — *Past association director. Health Department will be responsible for preparing codes.* (For further state information contact Nick G. Johnson, Director, Department for Human Resources, Commonwealth of Kentucky, Frankfort, Kentucky 40601.)

LOUISIANA

Charles E. Bishop, Chief Water Quality Section, Louisiana Health and Human Resources Administration, Division of Health, P. O. Box 60630, New Orleans, Louisiana 70160.

MAINE

Donald C. Hoxie, Director of Health Engineering, State of Maine, Department of Health and Welfare, Augusta, Maine 04330 — *Responsible for preparing water well drilling codes.*

MARYLAND

J. Roland Tubman, Executive Director, Maryland State Board of Well Drillers, Tawes State Office Building, Annapolis, Maryland 21401—*Handles licensing.* The Water Resources Administration is responsible for preparing water well drilling codes.

MASSACHUSETTS

Michael L. Bes[illegible], Principal Civil Engineer, Water Resources Commission, Leverett Saltonsall Building, Government Center, 100 Cambridge Street, Boston, Mass. 02202 — *Responsible for codes and licensing.*

MICHIGAN

Donald K. Keech, P. E. Chief, Ground Water Quality Control Section, Department of Public Health, 3500 N. Logan, Lansing, Michigan 48914 — *Responsible for codes and registering.*

MINNESOTA

Edwin H. Ross, Senior Hydrologist, Ground Water Quality Control Unit, Minnesota Department of Health, 171 S.E. Delaware St., Minneapolis, Minnesota 55440 — *Handles codes and licensing of contractors.*

MISSISSIPPI

Jack W. Pepper, P. E., State Water Engineer, Mississippi Board of Water Commissioners, 416 N. State Street, Jackson, Mississippi 39201 — *Responsible for the licensing of contractors.*

MISSOURI

Robert S. Miller, P. E., Missouri Department of Natural Resources, P. O. Box 1368, Jefferson City, Missouri 65101. — *Division of Health handles regulations for drilling of water supply wells, other than public water supply system.*

MONTANA

Mrs. Diana Cutler, Department of Professional and Occupational Licensing, LaLonde Building, 42½ North Main, Helena, Montana 59601 — *Handles licensing of contractors.*

A. W. Clarkson, Pe. E., Water Quality Bureau, Environmental Sciences Division, Department of Health and Environmental Sciences, Helena, Montana 59601 — *Responsible for codes.*

NEBRASKA

Clifford L. Summers, P. E. Director, Department of Health, Division of Environmental Engineering, Lincoln Building, 1003 "O" Street, Lincoln, Nebraska 68508 — *Prepares codes.*

NEVADA

William J. Newman, Ground Water Engineer, Department of Conservation and Natural Resources, Division of Water Resources, 201 South Fall Street, Carson City, Nevada 89710 — *Handles codes and licensing.*

NEW HAMPSHIRE

Lindsay M. Collins, P.E., Director of Municipal Services, Water Supply and Pollution Control Commission, Prescott Park, P. O. Box 95, 105 London Road, Concord, New Hampshire 03301.

NEW JERSEY

Joseph W. Miller, Jr., Principal Geologist, Bureau of Geology and Topography, Department of Environmental Protection, P. O. Box 2809, Trenton, New Jersey 08625 — *Licenses drillers and prepares codes.*

NEW MEXICO

S. E. Reynolds, State Engineer, Water Rights Division, Bataan Memorial Building, State Capitol, Santa Fe, New Mexico 87501 — *Responsible for codes and licensing of artesian wells only.*

John Wright, Environmental Protection Agency for State of New Mexico — *Responsible for other ground water development.*

NEW YORK

Louis M. Concra, Jr., Central Permit Agent, New York State Department of Environmental Conservation, 50 Wolf Road, Albany, New York 12201.

Daniel J. Larkin, N.Y. State Department of Environmental Conservation, Environmental Analysis Unit, Building 40, SUNY Campus, Stony Brook, N.Y. 11794 — *Long Island drillers only.*

NORTH CAROLINA

Harry M. Peek, Chief Ground Water Division, Department of Natural and Economic Resources, Box 27687, Raleigh, North Carolina 27611 — *Responsible for codes.*

Mrs. Marie Harrison, Executive Secretary, State of North Carolina Board of Water Well Contractor Examiners, P.O. Box 17261, Raleigh, North Carolina — *Handles licensing.*

NORTH DAKOTA

W. Van Heuvelen, Chief, Environmental Health and Engineering Services, Department of Health, State Capitol, Bismarck, North Dakota 58501 — *Prepares the codes.* (The Board of Water Well Contractors is responsible for licensing.)

OHIO

Russell B. Stein, The Ohio Environmental Protection Agency, Division of Ground Water, Office of Public Supply, 361 East Broad Street, P O Box 1049, Columbus, Ohio 43216 — *Well drilling codes and well contruction.*

OKLAHOMA

Forrest Nelson, Executive Director, Oklahoma Water Resources, and J. A. Wood, Ground Water Division

Chief, Oklahoma Water Resources Board, Fifth Floor, Jim Thorpe Building, Oklahoma City, Oklahoma 73105—*Licenses all persons, firms, and corporations drilling fresh water wells with the exception of domestic water well drillers.*

John A. Armstron, Director, Sanitation and Plumbing Division, State Department of Health, Northeast 10th and Stonewall, Oklahoma City, Oklahoma 73105—*Prepares drilling codes.*

OREGON

Leo G. Farr, Jr., Public Health Engineering, Department of Human Resources, Health Division, 1400 S.W. 5th Avenue, Portland, Oregon 97201—*Prepares codes for public water supply wells only.*

William S. Bartholomew, Supervisor, Ground Water Division, 1178 Chemeketa Street N.E., Salem, Oregon 97310—*Responsible for codes on all other wells and licensing of water well drilling contractors.*

PENNSYLVANIA

Paul S. Zimmerman, Chief, Water Facilities Section, Division of Community Environmental Services, P. O. Box 2063, Harrisburg, Pennsylvania 17120—*Will be responsible for coding and licensing.*

RHODE ISLAND

Henry F. Munroe, Staff Director, Water Resources Board, 265 Melrose Street, P. O. Box 2772, Providence, Rhode Island 02907—*Administers licensing.*

SOUTH CAROLINA

William E. Stilwell, Jr., P.E., Chief Bureau of Special Environmental Programs, South Carolina Department of Health and Environmental Control, 2600 Bull Street, Columbia, S. C. 29201—*Prepares codes.*

SOUTH DAKOTA

John Hatch, Chief Engineer, Department of Natural Resource Development, Water Rights Commission, Foss Building, Pierre, South Dakota 57501—*Prepares codes and licenses contractors.*

TENNESSEE

Robert A. Hunt, Director, Tennessee Department of Conservation, Division of Water Resources, 6213 Charlotte Avenue, Suite 107, Nashville, Tennessee 37209—*Codes and licensing.*

TEXAS

Charles K. Foster, Department of Health Resources, 1100 West 49th Street, Austin, Texas 78756—*Prepares drilling codes.* Texas Water Development Board, Water Well Drillers Section, P. O. Box 13087, Capitol Station, Austin, Texas 78711—*Licensing.*

UTAH

Dee C. Hansen, State Engineer, Department of Natural Resources, Division of Water Rights, 442 State Capitol, Salt Lake City, Utah 84114—*Responsible for codes and licensing.*

VERMONT

David Butterfield, Chief, Ground Water Management, Agency of Environmental Conservation, Department of Water Resources, Management and Engineering Division, Montpelier, Vermont 05602—*Protects, regulates and controls ground water of state. Also licenses contractors.* (The Health Department regulates wells drilled for public water supply systems—ten or more connections.)

VIRGINIA

Norman Phillips, Jr., Director, Bureau of Sanitary Engineering, State Health Department, 109 Governor Street, Richmond, Virginia 23219.

WASHINGTON

Robert L. Wubbene, P. E., Supervisor of Technical Services, Department of Social and Health Services, Health Services Division, Box 1788, Olympia, Washington 98504—*Code information.*

John Swerda, Department of Ecology, St. Martin's College, Olympia, Washington 98504—*Licensing.*

WEST VIRGINIA

James H. Hodges, P.E., Water Supply Program, Division of Sanitary Engineering, Department of Health, Charleston, West Virginia 25305.

WISCONSIN

Thomas A. Calabrese, P. E. Chief, Private Water Supply Section, Department of Natural Resources, Box 450, Madison, Wisconsin 53701—*Reponsible for codes and licensing.*

WYOMING

Richard G. Stockdale, Ground Water Geologist, State Engineer's Office, State Office Building, Cheyenne, Wyoming 82002—*Licensing.* (The Health Department, Environmental Protection Agency and the State Engineer's Office are responsible for preparing drilling codes.)

DISTRICT OF COLUMBIA

Malcolm C. Hope, Director, Environmental Health Administration, 415 12th Street, N.W., Room 308, Washington, D. C. 20004.

GUAM

Geoffrey K. Burke, Guam Environmental Protection Agency, P. O. Box 2999, Agana, Guam 96910.

PUERTO RICO

Secretary of Water Resources, Department of Natural Resources, Box 5887, Puerta de Tierra, Puerto Rico 00906. ■

PITLESS UNIT & ADAPTER UPDATE

MANY SANITARIANS and county agents, reports Durward Humes, executive secretary of the Pitless Division of the Water Systems Council, aren't aware of the variety of styles and sizes of adapter equipment available. There are *adapters,* designed to be assembled and installed in the field; they are available in compression gasket, saddle compression, and weld on styles. Then there are *units,* which are delivered as factory assembled equipment ready for attachment to the well casing. There are also *above ground discharge* designs.

Further, many outside the industry aren't aware that adapter equipment is available to fit well sizes from two to twenty inches. Buyers have choices as to the types of caps, which complete the well, and (in the case of municipal and

CONTINUED ON PAGE 38

c-i

APPENDIX C

FUNDAMENTALS OF GROUNDWATER HYDROLOGY

Excerpted from the January 1981 Course Notes
of a one-week short course on
Groundwater Pollution and Hydrology
Lecturers: R.W. Cleary, D.W. Miller
and G. F. Pinder

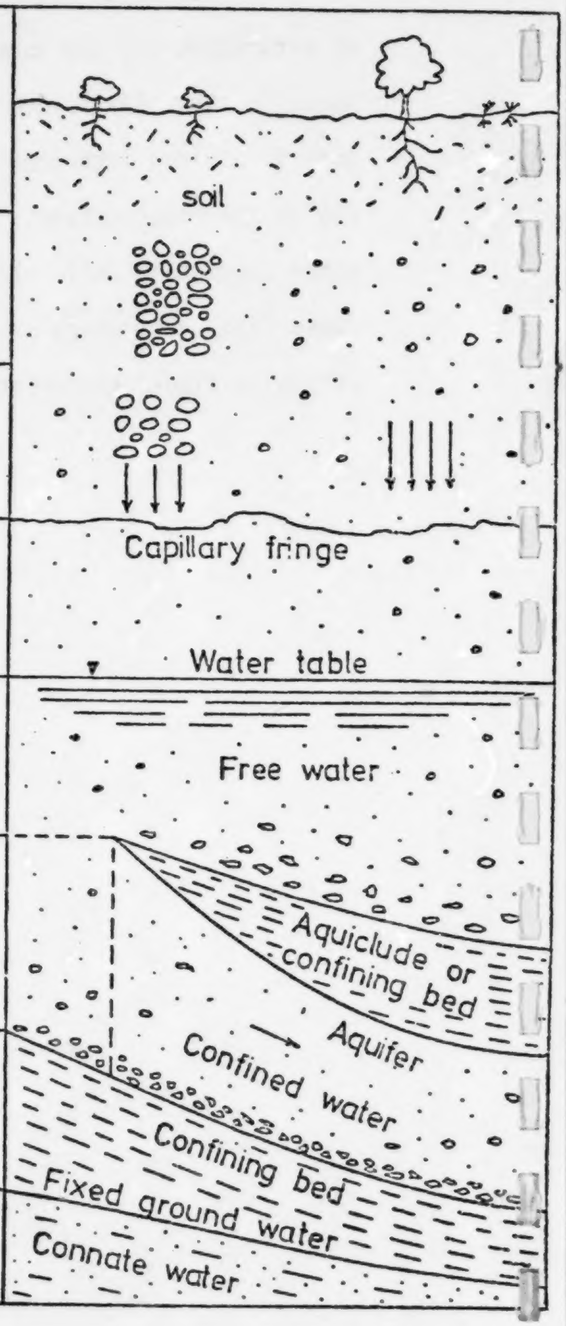
Sponsored by: Princeton Associates
P.O. Box 2010
Princeton, New Jersey
08540

January 1981 Edition

FUNDAMENTALS OF GROUNDWATER HYDROLOGY: CLASSIFICATION OF SUBSURFACE WATER

Subsurface water occurs in two distinct zones, the zone of saturation and the zone of aeration. The upper zone, where pore space is partially filled with water, is the zone of aeration. This zone is divided into four belts, in which a gradual transition from one to the other exists. In the lower zone, the zone of saturation, water completely fills the pore space. This is the only part of subsurface water which is properly referred to as groundwater. The following figure summarizes subsurface water classification:

Under-Saturated Zone or Zone of Aeration	Soil water is near enough to the surface to be reached by the roots of common plants. Some soil water remains after plants begin to wilt.
	Stored or pellicular water adheres to soil particles and is not moved by gravity.
	Gravity or vadose water moves down by gravity throughout zone.
Suspended Water	Capillary water occurs only in the capillary fringe at bottom of the zone of aeration.
phreatic surface Saturated Zone Ground Water	Free water occurs below the water table. Movement controlled by the slope of the water table.
	Confined or artesian water occurs beneath a confining stratum. results in the formation of a piezometric surface
	Fixed ground water occurs in subcapillary openings of clays, silts, etc. Not moved by gravity.
	Connate water entrapped in rocks at the time of their deposition.

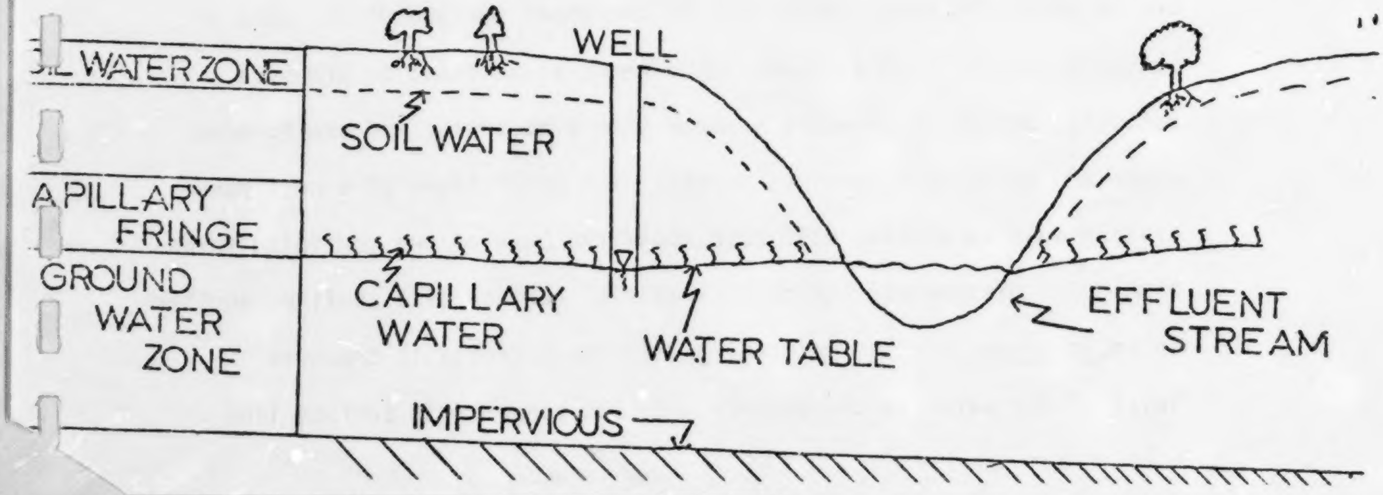

soil
Capillary fringe
Water table
Free water
Aquiclude or confining bed
Aquifer
Confined water
Confining bed
Fixed ground water
Connate water

Zone of Aeration:

In this zone, the interstices are occupied by water and air, except when excessive water enters the ground temporarily, e.g., irrigation or rainfall. The soil water zone extends from the ground surface to beyond the major root zone. It has been extensively studied by soil scientists because of its importance to vegetation. Pellicular water is non-moving water held by hydroscopic and capillary forces. Gravitational water is excess water which moves downward after pellicular demands and soil water demands have been met. The capillary zone extends from the water table up to the limit of capillary rise, which depends on the type of soil. It may range from 1/4 inch (gravel) to 3 feet or more (clay).

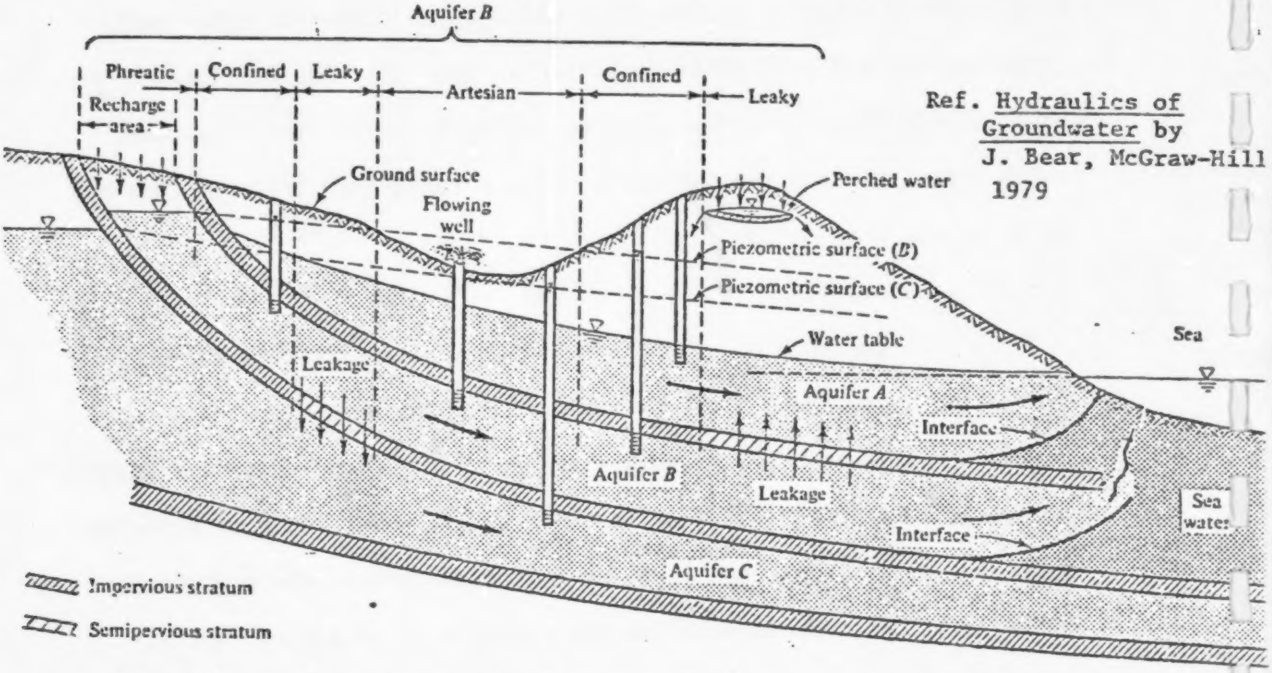
Zone of Saturation:

In the zone of saturation all the interstices are filled with water under hydrostatic pressure (i.e., the pressure at a given point is caused only by the height of the fluid column above the point). The upper surface of this zone is known as the water table or phreatic surface. It is a surface, in an unconfined material, along which the hydrostatic pressure is equal to the atmospheric pressure. Wells, springs and streams are fed by water from the zone of saturation.

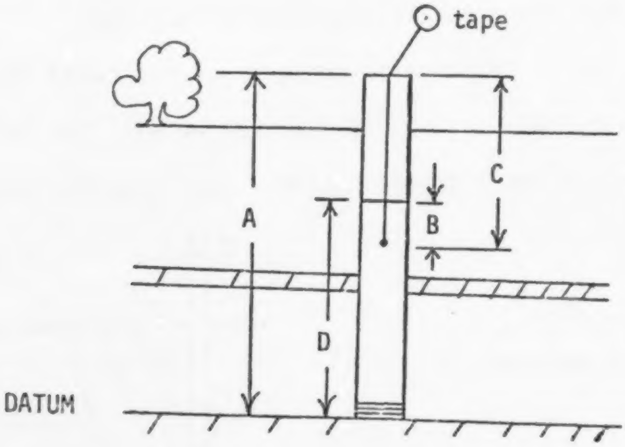


AQUIFERS:

An aquifer is a geologic formation which will yield significant quantities of water. It is estimated that over 90% of all developed aquifers consist of unconsolidated sand and gravel. Most aquifers are of very large areal (horizontal) extent and are, in fact, large underground reservoirs. Aquifers are classified as confined or unconfined depending upon the absence or presence of a water table (phreatic surface at atmospheric pressure). An unconfined aquifer is one in which the water table acts as the upper surface of the zone of saturation. Confined aquifers (also known as artesian or pressure aquifers) are under pressure greater than atmospheric and are bounded above and below by impervious strata. The water level of a well penetrating such an aquifer will rise above the base of the confining formation. The piezometric (or potentiometric) surface of a confined aquifer is an imaginary surface coinciding with the hydrostatic pressure level of the water in the aquifer. If the piezometric surface lies


Aquifer *B*
Phreatic
Confined
Leaky
Recharge area
Artesian
Confined
Leaky
Ground surface
Flowing well
Perched water
Piezometric surface (*B*)
Piezometric surface (*C*)
Water table
Sea
Leakage
Aquifer *A*
Interface
Aquifer *B*
Leakage
Sea water
Interface
Aquifer *C*
Impervious stratum
Semipervious stratum

Ref. Hydraulics of Groundwater by J. Bear, McGraw-Hill 1979 above the ground level, a flowing well results (sometimes called an artesian well; artesian may also be used to simply mean confined). A region supplying water to an aquifer is known as a recharge area. The change of water levels in wells penetrating confined aquifers result primarily from changes in pressure rather than from changes in storage volumes. The opposite is true for unconfined aquifer. By definition, a confined aquifer becomes an unconfined aquifer when the piezometric surface falls below the bottom of the confining bed. The piezometric surface of an aquifer is often determined by measuring the water levels in a number of observation wells (also called piezometers). The water levels are measured relative to a given datum. The measurement may be made in a number of ways, but one of the most common and also reasonably accurate (to approximately .005 ft.) methods is to use a steel surveyor's tape. The following figure illustrates how to determine the piezometric head in an observation well.



A = top of casing elev. above datum

B = length of wetted tape

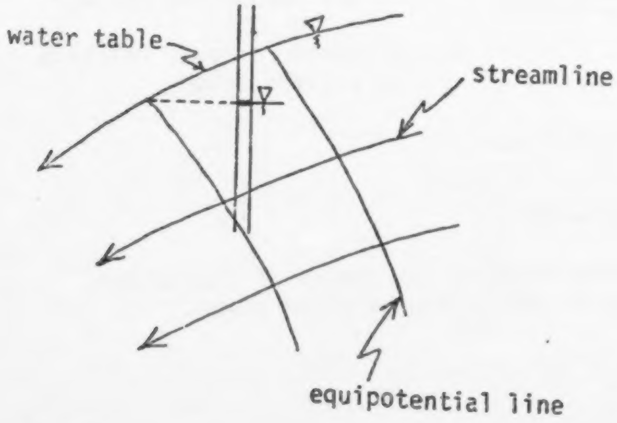
C = tape reading, read exactly at the top of the casing

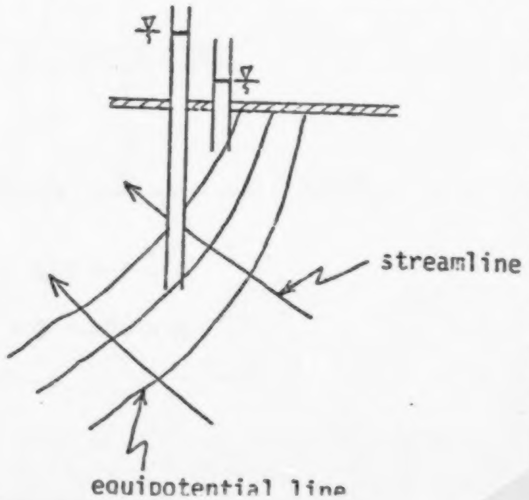
D = piezometric head, relative to a given datum

C - B = DTW = depth to water

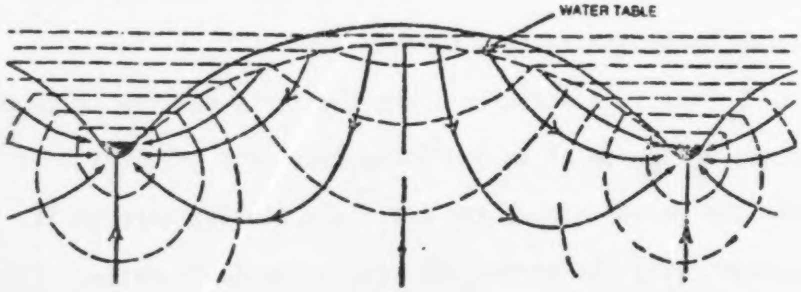
A - DTW = D = piezometric head at the center of the screen, relative to the indicated datum plane.

When the flow in the aquifer is essentially horizontal, the equipotential surfaces are vertical and the depth from the land surface to the piezometer screen is immaterial; regardless of where the screen is set, the potentiometric head will be essentially the same. However, if the flow is not horizontal (e.g., near recharge or discharge areas, or near partially penetrating wells) a different piezometric head will be observed for each different screen depth (measured from the same land surface). In this case, a properly installed observation well will have a relatively short screened section which will indicate the average piezometric head (e.g., at the screen center) at the depth of penetration. In water table aquifers, the flow, in most cases, can never be horizontal. For this reason, the water level in an unconfined observation well only approximately indicates the water table at that point. It exactly indicates the piezometric head at the point where the water enters the well (assuming a small screen length). This piezometric head equals the value of the potentiometric surface which intercepts the well openi . This potentiometric surface, in turn, intercepts the water table surface and numerically equals the height of the water table above a datum plane at the point of interception. While it is true that the water table, in general, will not be horizontal, it is also true that its slope is often relatively small and the changes in height are small relative to the overall saturated thickness. In many cases, one may assume virtual horizontal flow (as we will see in chap. 6 with the Dupuit assumptions) with ample justification. The above discussion is better understood with a figure.



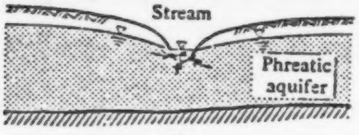


In an introductory chapter such as this, it is not important that one mathematically understand the nature of streamlines and equipotential lines. In chapter 6 we will discuss the mathematical models which are used to determine the equipotential surfaces. At this point, one should appreciate that there are an infinity of equipotential lines and streamlines and that these lines are always perpendicular (isotropic systems) to each other. Groundwater may be visualized as moving along streamlines from higher equipotential surfaces to lower equipotential surfaces. The equipotential surfaces themselves may be constructed from water level measurements in a series of observation wells. Because most aquifers are thin relative to their areal dimensions (e.g., hundreds of feet or less vs. many thousands of feet in horizontal dimensions), in most cases of practical interest, one may neglect vertical flow components and assume essentially horizontal flow. This means the equipotential surfaces are all vertical and we assume the water level in an observation well would be the same no matter what depth we set the screen. However, also keep in mind that this assumption is not nearly as valid near areas of recharge or discharge. The following figure is an idealized cross-section of an interstream area being recharged by precipitation and discharging to its adjoining streams. Observe that wells near the streams will tap higher piezometric heads as depth increases. That is, it is possible to have a *flowing water table* well. The water level will rise to the height of a point on the water table which intersects the potentiometric line, which in turn intersects the opening of the well. One should also observe that wells on the hill tap lower piezometric heads as their screen depth increases.

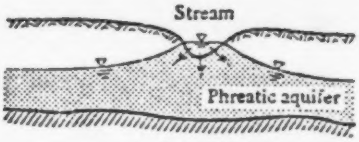


INFLUENT AND EFFLUENT STREAMS:

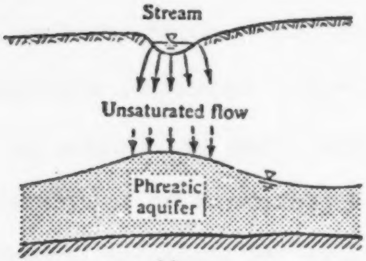
When the water level (measured from a datum, e.g., bedrock) in a stream is higher than the surrounding water table elevation, water infiltrates from the stream into the unconfined aquifer and the stream is termed influent. When the hydrologically connected water table is higher than the stream, water flows from the aquifer into the stream and the stream is termed effluent.


Stream
Phreatic aquifer

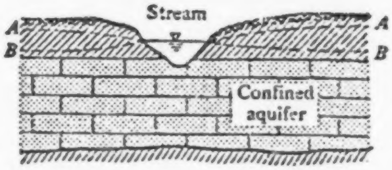
(a)


Stream
Phreatic aquifer

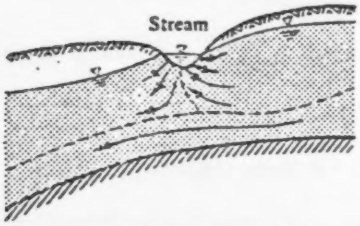
(b)


Stream
Unsaturated flow
Phreatic aquifer

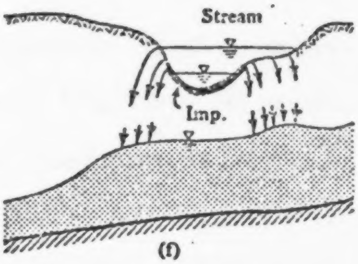
(c)


Stream
A
B
A
B
Confined aquifer

(d)



Ref: Hydraulics of
Groundwater,
J. Bear, McGraw-Hill
1979



(f)

AQUIFER PARAMETERS:

Aquifers are characterized by their ability to conduct water under a given hydraulic gradient and by their storativity.

Hydraulic Conductivity (K = L/T):

This is a measure of the aquifer's ability to conduct water under the influence of an impressed hydraulic gradient. It is a property of both the porous medium and the fluid flowing through it. The higher the conductivity the better the aquifer conducts water. Closely related to the conductivity is the aquifer transmissivity (T) which indicates the ability of the aquifer to transmit water through its entire thickness; it is equal to the product of the conductivity and the thickness of the aquifer, b(T = Kb).

Storage Coefficient:

The storage coefficient (S) is the volume of water that an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in the component of head normal to that surface. For a vertical column one foot by one foot extending through an aquifer, the storage coefficient (S) equals the volume of water (in cubic feet) released from the aquifer when the piezometric surface declines one foot. In most confined aquifers S ranges from .00005 to .005, indicating that large pressure changes over extensive areas are required to produce substantial water yields. For example if S equals .0003, 300 ft^3 of water are released from storage under an area 1000 feet on a side (1,000,000 ft^2) when the piezometric head declines 1 foot. S is also called the confined storativity coefficient.

The storage coefficient for unconfined aquifers is essentially equal to its specific yield. Specific yield is the volume of water that a saturated soil will yield per unit volume of aquifer under the sole influence of gravity. It is also called the drainable porosity or effective porosity. For uniform sand, the specific yield may equal .30 (30%). However most unconfined aquifers range from 10 to 30 % with 20 % being an average figure. If one compares the numerical values of specific yield and storage coefficient(confined aquifers) , it is obvious that for the same volume of discharge (or recharge), changes in the"piezometric surface" elevations are much larger in a confined aquife than in a water table aquifer.

Water recharged to or discharged from an aquifer represents a change in the storage volume of the aquifer. For unconfined aquifers this change in volume may be calculated by multiplying the specific yield by the change in volume of the aquifer over a period of time. In confined aquifers, changes in pressure produce only small changes in storage volume. Water that is released from a confined aquifer by a decline in the total poteniometric head (e.g., by pumping) comes from two sources associated with the elastic properties of the aquifer: 1) about 60% of the water is released due to the compression of the intergranular skeleton by the overburden; 2) 40% of the water released results from an expansion of water caused by a density decrease with decreasing pressure. Specific storage (S_s) describes the net effect of these two sources. It is defined as the volume of water which a unit volume of the aquifer releases from storage because of expansion of the water and compression of the aquifer under a unit decline in the average head. We will use this in chapter 6 in deriving a fundamental equation of groundwater flow.

MOVEMENT OF GROUNDWATER

A basic understanding of the natural paths and rates of groundwater movement will be very useful in evaluating groundwater pollution problems. The flow of groundwater depends on many factors, including the geologic structure and the prevailing recharge and/or discharge phenomena operating on the boundaries and within the system. Groundwater is an integral part of the hydrologic cycle and therefore is continually in motion from areas of natural and artificial recharge to areas of natural and artificial discharge. It flows principally under the influence of gravity from levels of higher potential to levels of lower potential (where its potential is the result of elevation and pressure). This decrease in potential along the seepage path is the result of friction between the water and the soil matrix. In relatively wet areas, precipitation keeps the water table near the ground surface, and the consequent mounding of the water beneath interstream areas results in an easily predictable movement of water.

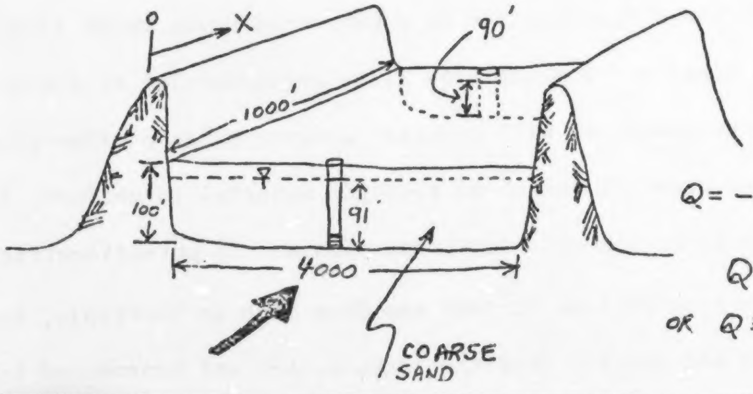
In arid regions, the movement of water may be much more difficult to estimate.

In vertical infiltration, water first satisfies the soil moisture and pellicular demands,with any excess percolating by gravity and pressure differences to the water table. If excess amounts are not reached, the water (or wastewater in the case of spray irrigation of sewage, for example) will tend to stay in the zone of aeration until moved downward by excess rainfall or further irrigation. In the case of biologically degradeable wastes, this increased residence time together with a supply of oxygen [it's unsaturated]will be advantageous and should be designed for, if possible .

Groundwater movement can be predicted using Darcy's law. In 1856 Darcy, in his experiments with the flow of water through sand columns, determined that the flux of water through sand is proportional to the hydraulic gradient impressed. Mathematically, we state his findings in the following way:

$$q = Q/A = -K \frac{\Delta H}{\Delta X} \qquad \text{Eq. 12}$$

where q is the Darcy velocity [L/T], Q is the flow rate [L^3/T], A is the cross-sectional area perpendicular to the flow direction [L^2], K is the hydraulic conductivity [L/T], ΔH is the total potential head change [L] over the distance, ΔX [L]. To illustrate the use of eq.(1-12), consider a valley of uniform cross-sectional area in which the total head drops 1 foot/1000 feet and the conductivity is 900 ft/day. We calculate the total flow rate through the valley in the following way:



$$Q = -(91)(4000')(900'/\text{DAY})\left(\frac{90-91}{1000}\right)$$

$$Q = 327{,}600\ ft^3/\text{Day}$$

$$\text{OR } Q \cong 2{,}450{,}448\ \text{gal/DAY}$$

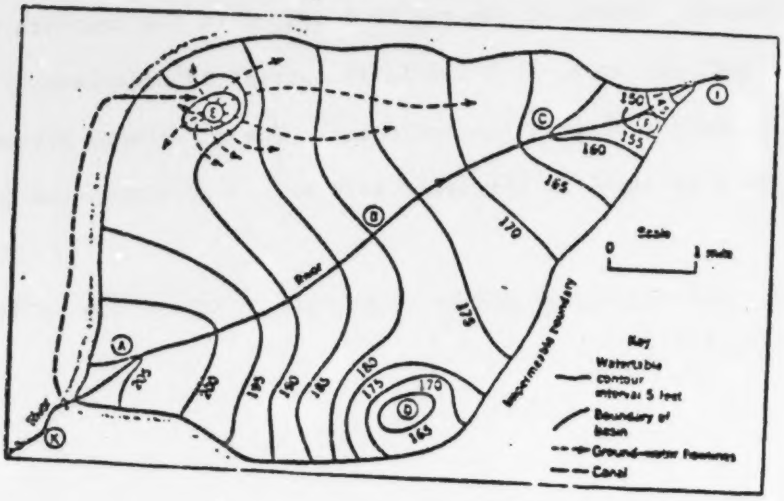
As we will learn later in subsequent chapters, q, the Darcy velocity, is a superfici velocity based on the total cross-sectional area (voids *and* solids). The seepage velocity (true velocity or particle velocity)is obtained by dividing q by n, the porosity .In the preceeding example, if n were equal to .25, the average velocity f a particle of water would be 3.6 ft/day. This does not necessarily equal the actual velocity between any two points in the aquifer, which may range from less than to more than 3.6 ft/day, depending on the flow path followed. However, as long as the parameters remain constant, it is a good estimate of the *average* velocity. In general groundwater moves from 5 feet/day to 5 feet/year.

Strictly speaking, horizontal groundwater flow will occur in isotropic, homogeneous, horizontal, confined aquifers of constant thickness. In the vicinity of recharge areas, discharge areas and partially penetrating wells, one can expect the flow pattern to be three-dimensional. Fortunately, for most cases of practical interest, the assumption of horizontal flow in aquifers is reasonable. If the aquifer is thin relative to its areal extent (almost always true) and if one is not near recharge/discharge areas the assumption is excellent. Under such circumstances, one assumes vertical equipotentials and the mathematical analysis is considerably simplified. In addition,the potential at a given areal location is the elevation of the water level at that point, regardless of the screen location.

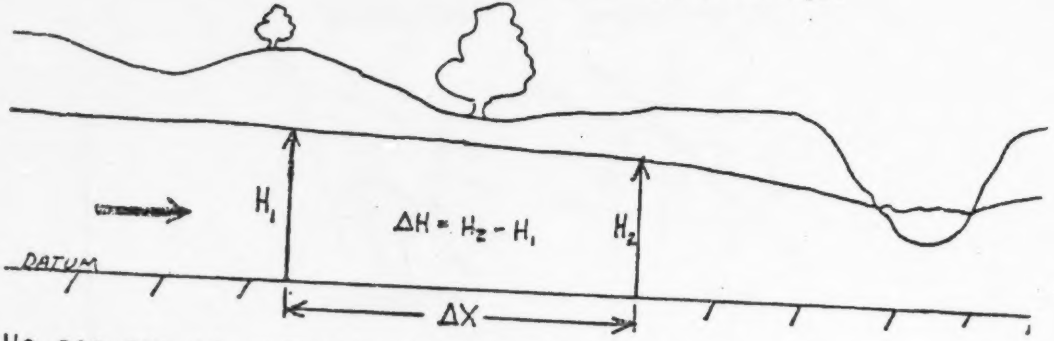
Groundwater flow is caused by a force potential which is directly proportional to the elevation of water levels in wells drilled in both confined and unconfined aquifers. One may determine the general direction of groundwater flow with potentiometric maps constructed from water-level elevations. Under the assumption of horizontal flow,a flow net can be constructed using water level contours as equipotential lines and drawing flow lines perpendicular to the contours.

To illustrate the method we will consider a water table aquifer whose hydraulic gradient is less than 1 % and whose geologic material is uniform. In this case the water table is an accurate representation of the potentiometric surface. An excellent example of a hypothetical contour map from such an isotropic, homogene aquifer is given by Davis and DeWiest (Hydrogeology, p. 49) and reproduced here

Reproduced from
best available copy.

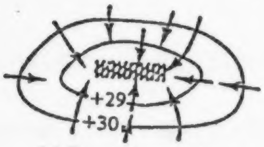

E
C
I
150
155
160
165
170
175
180
185
190
195
200
205
B
A
D
K
River
Scale
0
1 mile
Impermeable boundary
Key
Watertable contour interval 5 feet
Boundary of basin
Ground-water flowlines
Canal

The watertable contours are elevations of the water above a common datum plane (e.g. sea level at Sandy Hook, New Jersey).

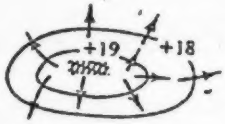

H_1
$\Delta H = H_2 - H_1$
H_2
DATUM
ΔX

We can see at point A that the watertable contour lines slope in the direction of the stream flow and at point C they slope against the stream flow (i.e., the peak at C points upstream). If we read the contours of the watertable on either side of the stream at A we see that the stream is influent at A; doing the same at C, we find the stream is effluent at this point. E represents an area of recharge (note the relatively high watertable contours) which comes from diverting some of the river water into a canal and transporting it to E (perhaps for irrigation). Point D is an area of heavy pumping in which the water level is lower than the stream level at B. Presently at B, the stream is neither influent or effluent(flow lines are tangent to the stream). However, continued pumping at D will make the contours shift so the river will be influent at B. At K and I, the stream is underlain by impervious strata and no infiltration or exfiltration occurs. The difference between the discharges at K and I is equal to the water lost or gained within the groundwater basin.

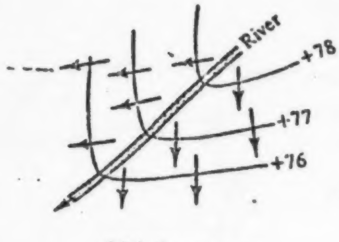
The previously discussed phenomena as well as other flow patterns are illustrate by the following figures:



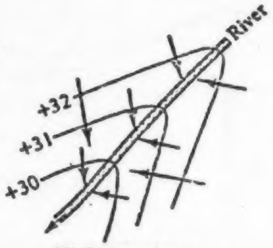
(a) Zone of pumping



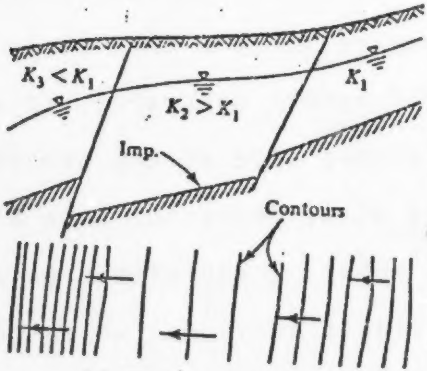
(b) Zone of recharge


River
+78
+77
+76

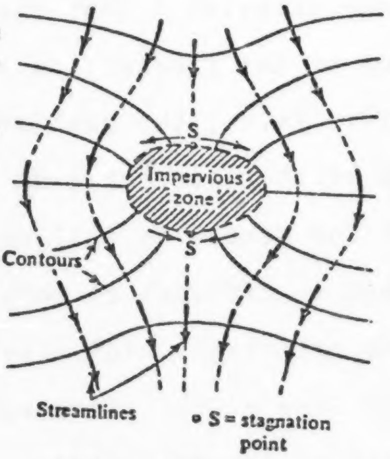
(c) Influent river


River
+32
+31
+30

(d) Effluent river

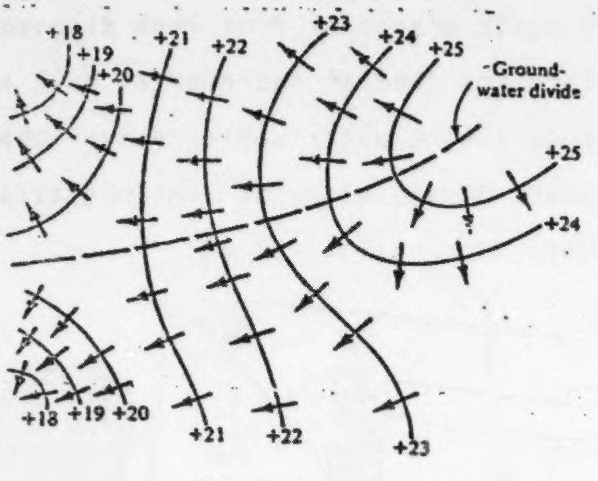

$K_3 < K_1$
$K_2 > K_1$
K_1
Imp.
Contours
$K_2 > K_1 > K_3$

(e) Effect of variable transmissivity

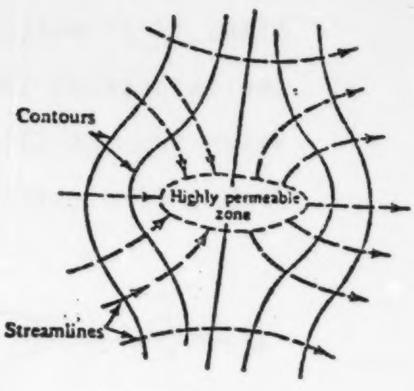

S
Impervious zone
S
Contours
Streamlines
S = stagnation point

(f) Effect of impervious zone

Ref: Hydraulics of Ground


+18
+19
+20
+21
+22
+23
+24
+25
Ground-water divide
+25
+24
+18
+19
+20
+21
+22
+23

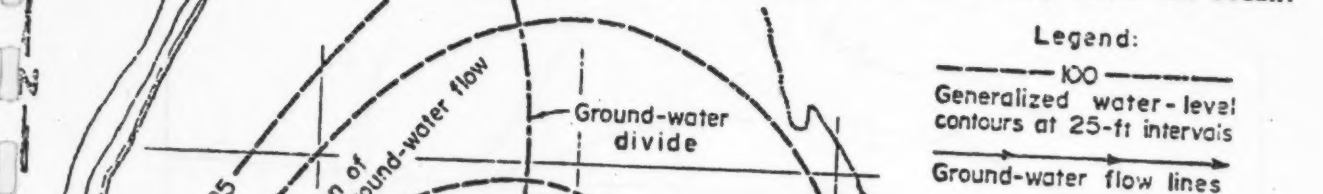
(i) A groundwater divide


Contours
Highly permeable zone
Streamlines

(g) Effect of highly permeable zone

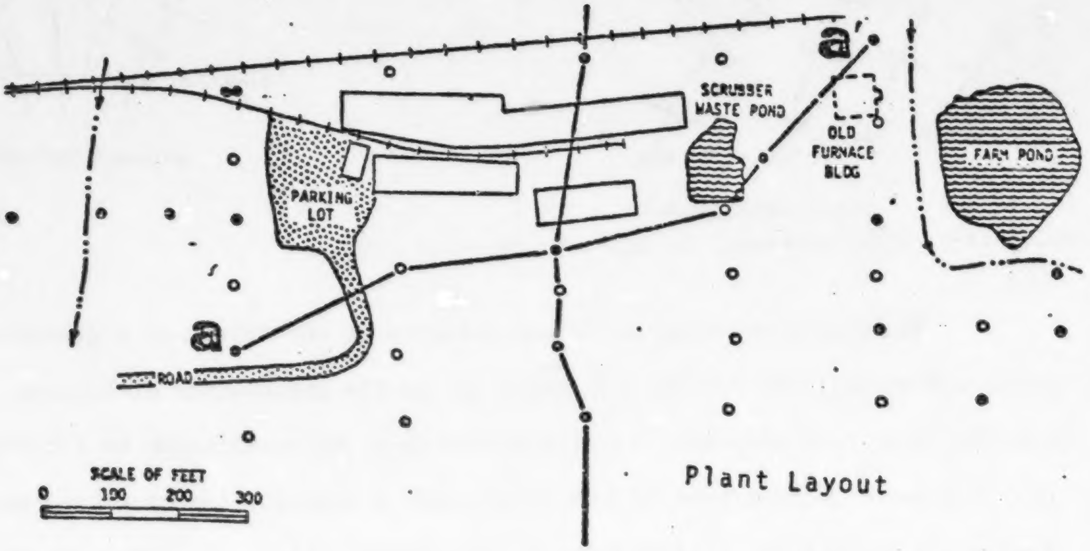
Ref: Hydraulics of Groundwater, J. Bear, McGraw-Hill, 1979

The following water table map illustrates the effect of a groundwater divide and an effluent stream. Perpendicular to the groundwater divide the potentiometric head does not change with distance. An equilibrium is established such that water falling east of the divide will eventually discharge in the river flood plain while water falling west of the divide will eventually reach the ocean.

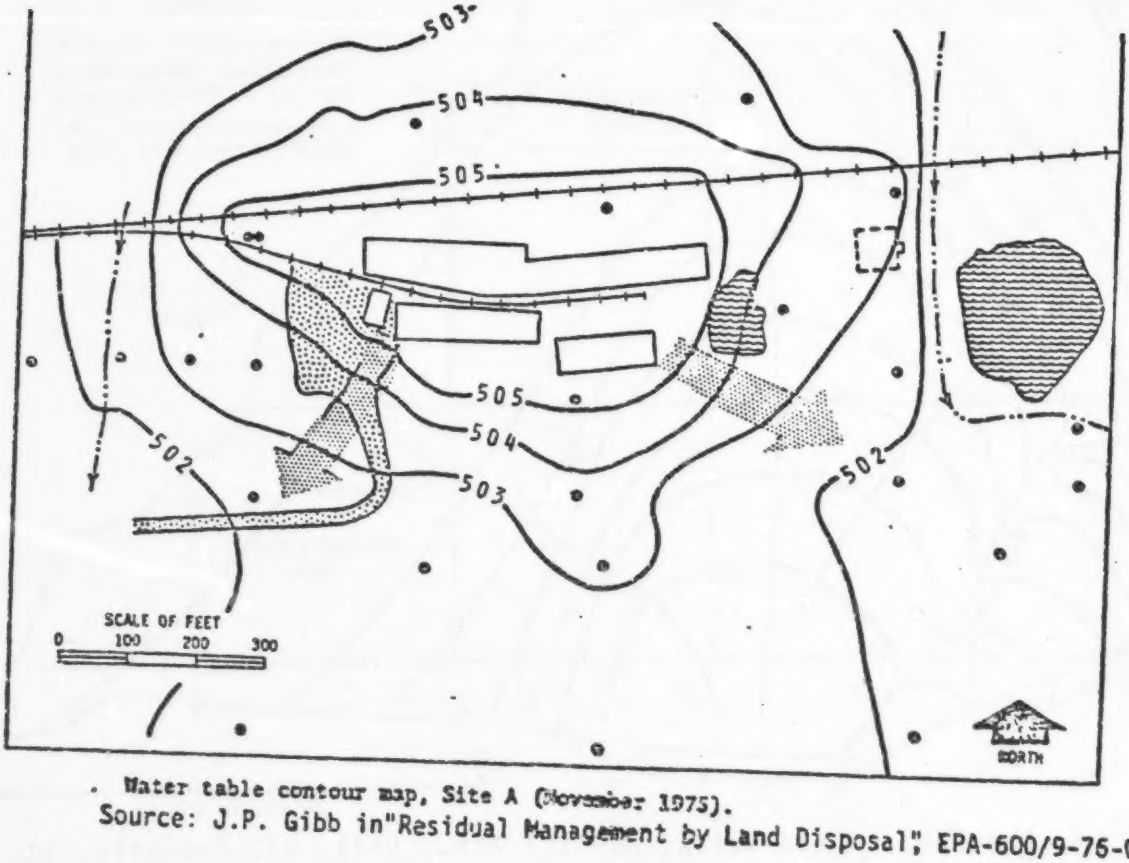

Ocean
25
50
75
100
125
150
175
200
Direction of ground-water flow
Ground-water divide
Legend:
100
Generalized water-level contours at 25-ft intervals
Ground-water flow lines
River flood plain
Bear Creek
Bedrock fault
Bedrock fault
Direction of ground-water flow
0
1
2
Scale in miles

Source: Groundwater and Wells, Johnson Div., Univ. Oil Products, St. Paul Minn.

Hazardous industrial waste migration from land disposal sites is of much concern to state and federal agencies as well as the industries themselves. The following water table contour map is taken from an Illinois State Water Survey study of zinc migration from a long established secondary zinc smelter plant.

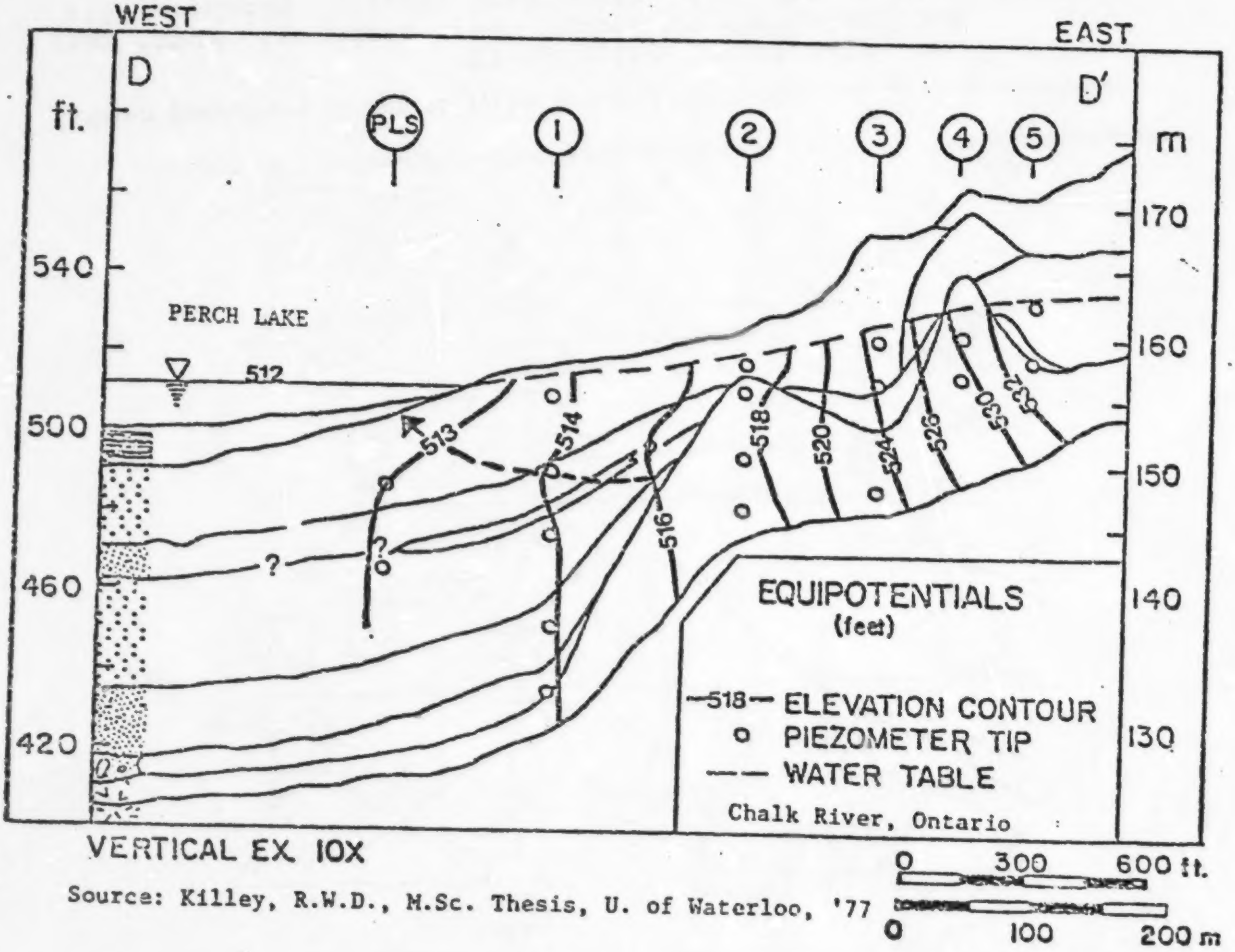

a'
SCRUBBER WASTE POND
OLD FURNACE BLDG
FARM POND
PARKING LOT
a
ROAD
SCALE OF FEET
0
100
200
300

Plant Layout


503
504
505
505
504
503
502
502
SCALE OF FEET
0
100
200
300
NORTH

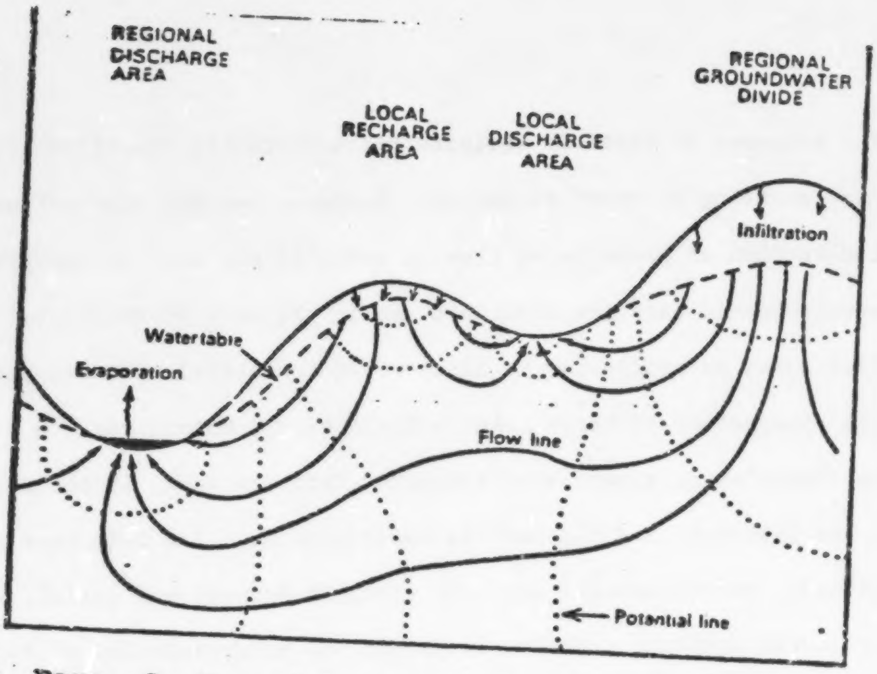
Water table contour map, Site A (November 1975).
Source: J.P. Gibb in"Residual Management by Land Disposal", EPA-600/9-76-015, 1976

The presence of vertical equipotentials certainly simplifies the field collection and plotting of water elevations. However, one may also estimate the general direction of groundwater flow in areas of recharge or discharge if adequate potentiometric data are available. As in the case of horizontal flow, one draws flow lines perpendicular to lines of equipotential. Potentiometric data from multiple piezometers at Perch Lake in Chalk River, Ontario may be used to estimate the direction of groundwater discharge into the lake. If the aquifer is homogeneous and isotropic and the flow is two-dimensional (in this case vertical and longitudinal), potentiometric maps are straight forward and useful; deviations from these criteria complicate the construction and interpretation of such maps.


WEST
EAST
D
D'
ft.
m
PLS
1
2
3
4
5
540
500
460
420
170
160
150
140
130
PERCH LAKE
512
513
514
516
518
520
524
526
530
532
?
EQUIPOTENTIALS
(feet)
—518— ELEVATION CONTOUR
o PIEZOMETER TIP
— — WATER TABLE
Chalk River, Ontario
VERTICAL EX. 10X
0 300 600 ft.
0 100 200 m

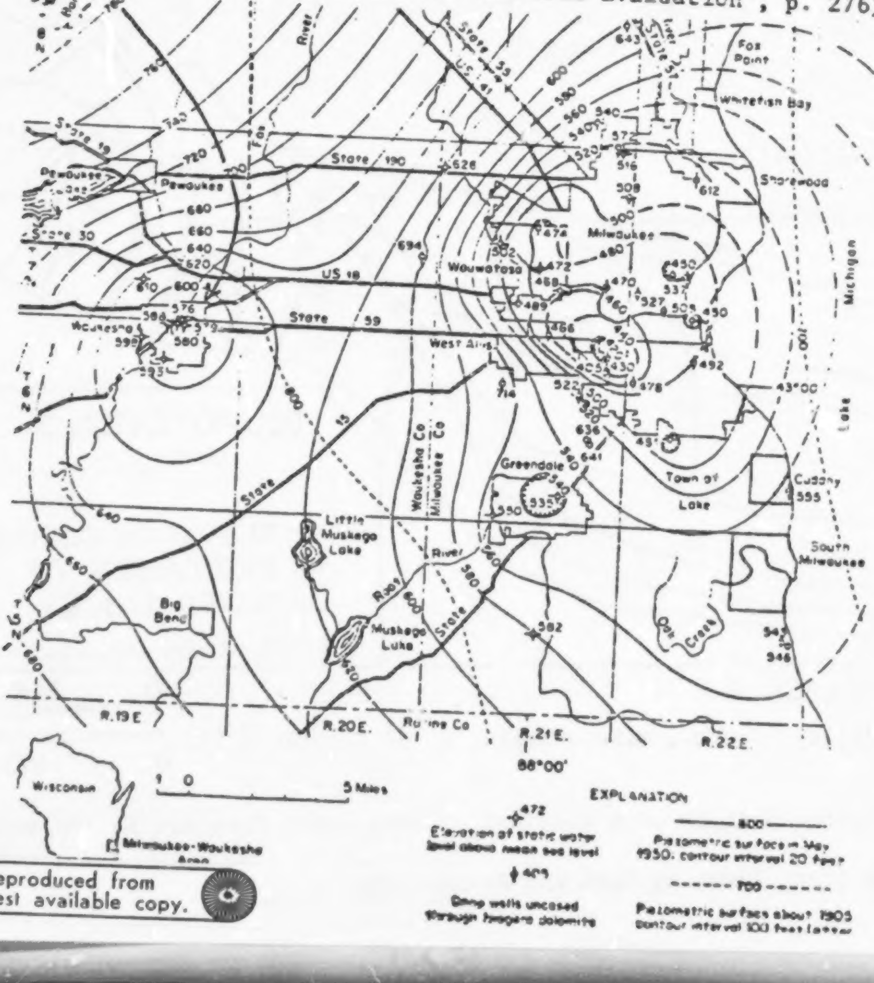
Source: Killey, R.W.D., M.Sc. Thesis, U. of Waterloo, '77

Another example of a vertical cross-section flow net is the analysis of regional and local flows by Born and Stephenson.

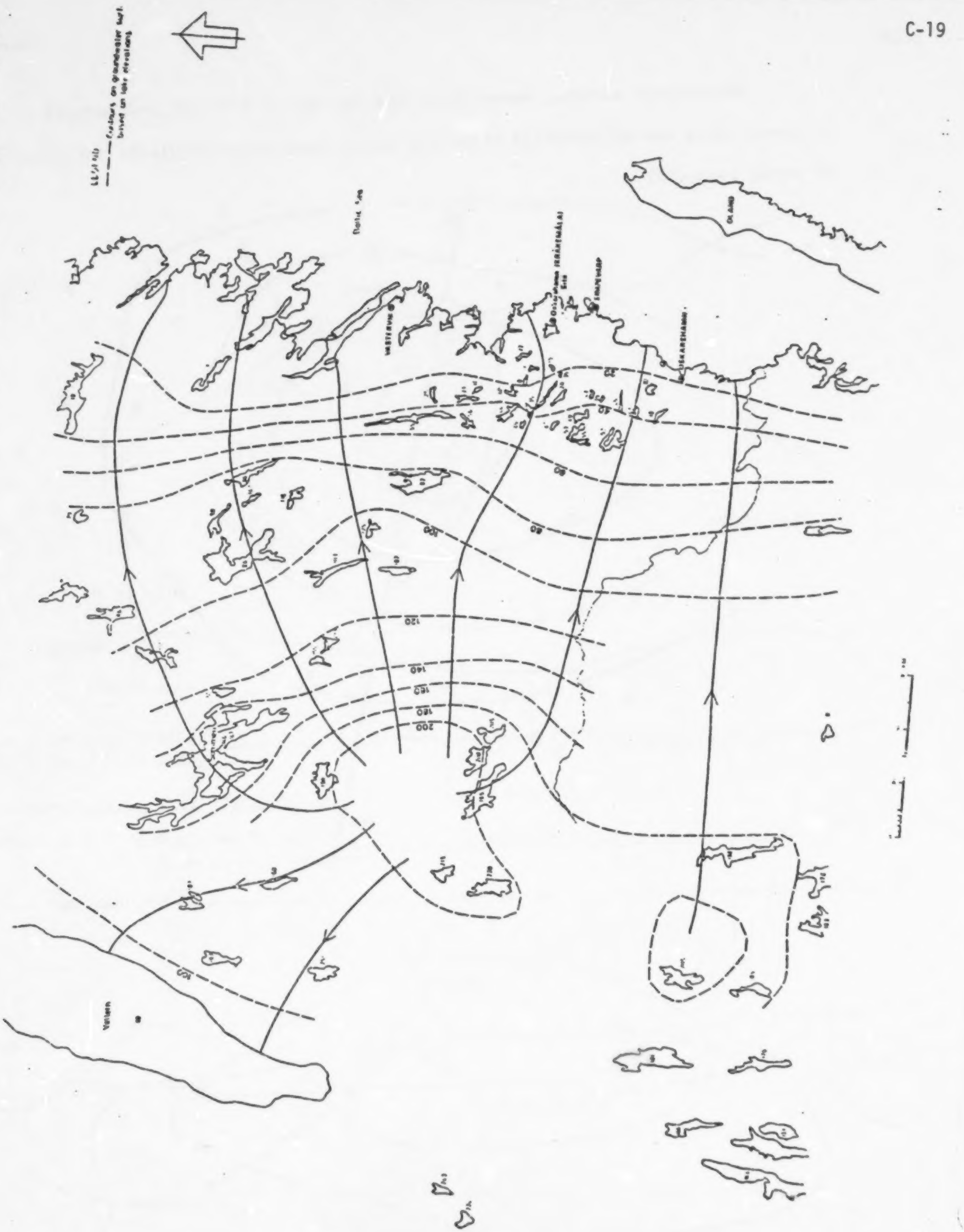

REGIONAL DISCHARGE AREA
LOCAL RECHARGE AREA
LOCAL DISCHARGE AREA
REGIONAL GROUNDWATER DIVIDE
Infiltration
Watertable
Evaporation
Flow line
Potential line

from Born, S. M. and D. A. Stephenson (1969). Hydrogeologic considerations in liquid waste disposal. Jour. Soil and Water Cons. 24(2):52-55.

Groundwater flow in large-scale regional aquifers can be determined using potentiometric maps (Walton, "Groundwater Resource Evaluation", p. 276):


Fox Point
Whitefish Bay
Shorewood
Milwaukee
Wauwatosa
West Allis
Pewaukee
Waukesha
Greendale
Town of Lake
Cudahy
South Milwaukee
Little Muskego Lake
Muskego Lake
Big Bend
Oak Creek
Waukesha Co
Milwaukee Co
Racine Co
Lake Michigan
State 190
State 30
State 59
State 55
State 57
US 41
US 18
Fox River
43°00'
88°00'
R.19E
R.20E.
R.21E.
R.22E.
Wisconsin
Milwaukee-Waukesha Area
0
5 Miles
EXPLANATION
472
Elevation of static water level above mean sea level
409
Drop wells uncased through Niagara dolomite
600
Piezometric surface in May 1950, contour interval 20 feet
700
Piezometric surface about 1905 contour interval 100 feet (after

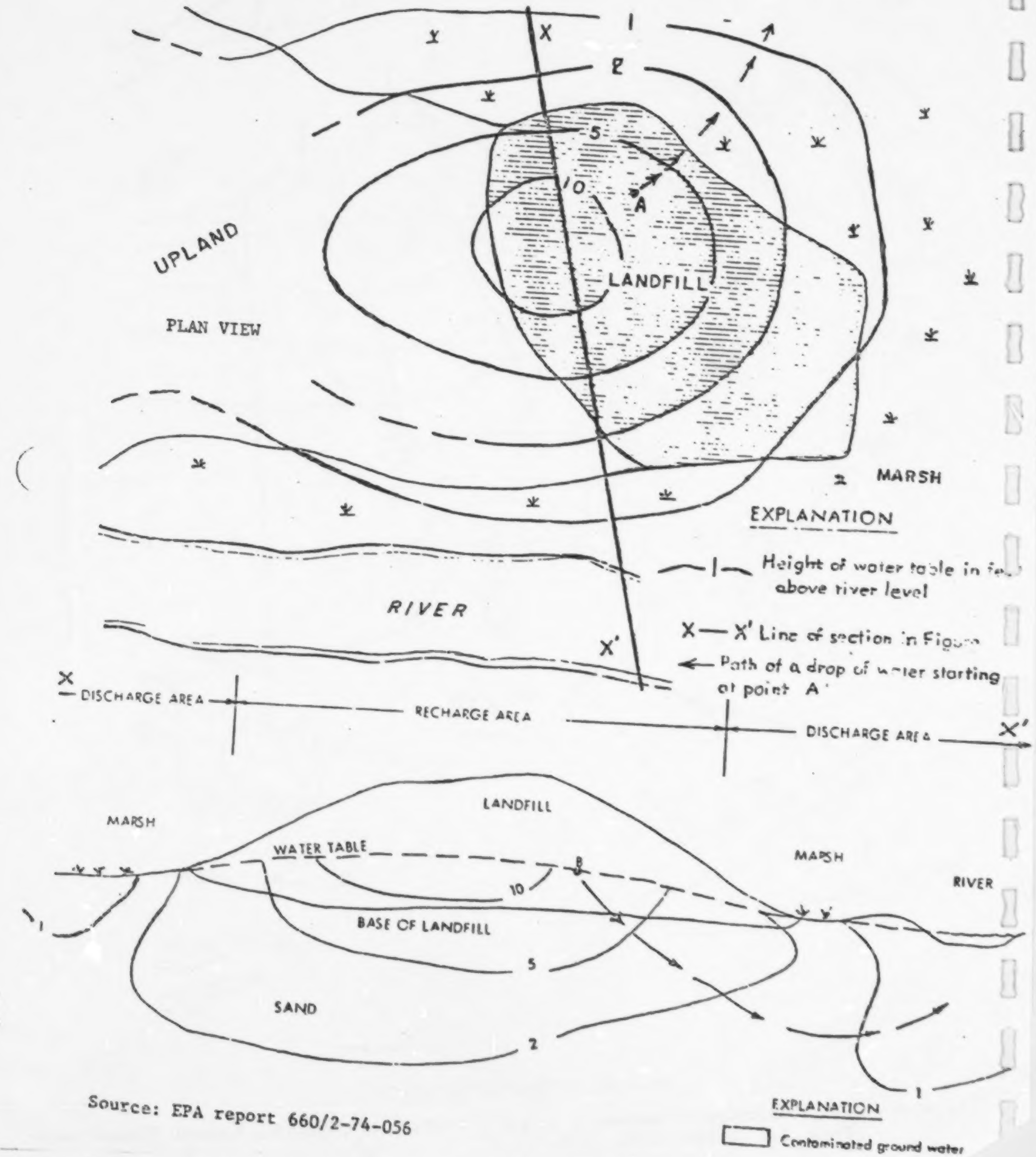
Reproduced from best available copy.


200
180
160
140
120
100
80
60

REGIONAL GROUNDWATER SURFACE

Reference: KBS, "Groundwater Movements Around a Repository", Teknisk Rapport 3, Hagconsult Fack. 102 40 Stockholm, 1977

Groundwater mounding under landfills results in vertical and lateral movement which can be estimated from flow lines that perpendicularly intersect li e of equal potential.

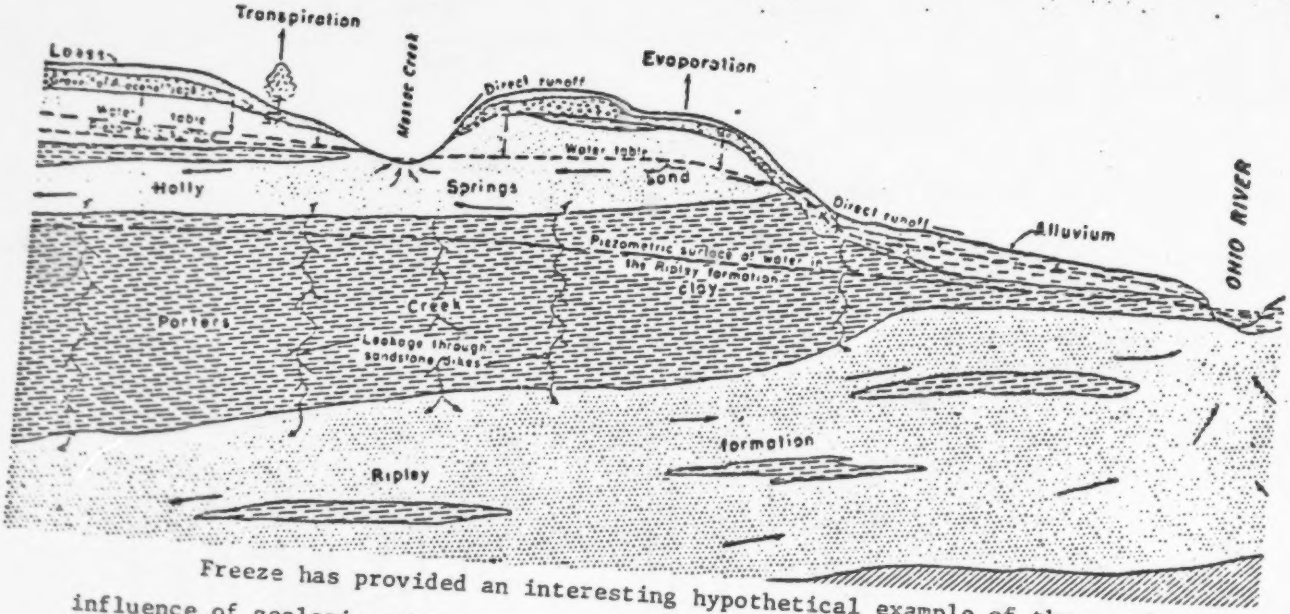


X
1
2
5
10
A
UPLAND
PLAN VIEW
LANDFILL
MARSH
RIVER
X'
EXPLANATION
1 Height of water table in fe above river level
X — X' Line of section in Figu
← Path of a drop of water starting at point A
X
DISCHARGE AREA
RECHARGE AREA
DISCHARGE AREA
X'
MARSH
LANDFILL
WATER TABLE
B
10
MARSH
RIVER
BASE OF LANDFILL
5
SAND
2
1
1
EXPLANATION
Contaminated ground water

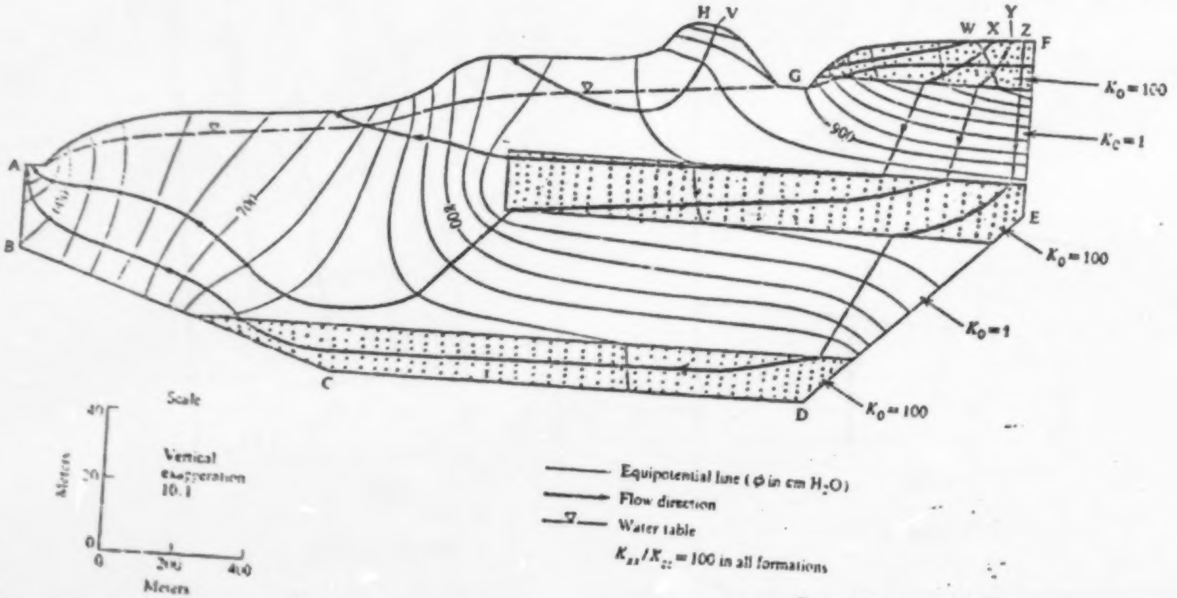
Source: EPA report 660/2-74-056

Flow Under Geologic Complications:

The preceeding water table maps illustrate simple but also common examples of how one might estimate groundwater movement in elementary water table situations. As one might imagine, however, many flow problems are extremely complex and require a lengthy, careful analysis before one can be certain where all the water is moving. The following diagram from the Paducah, Kentucky area is an example of a complex flow pattern (see Water Supply Paper 1417 of the U.S.G.S and the Johnson well manual).

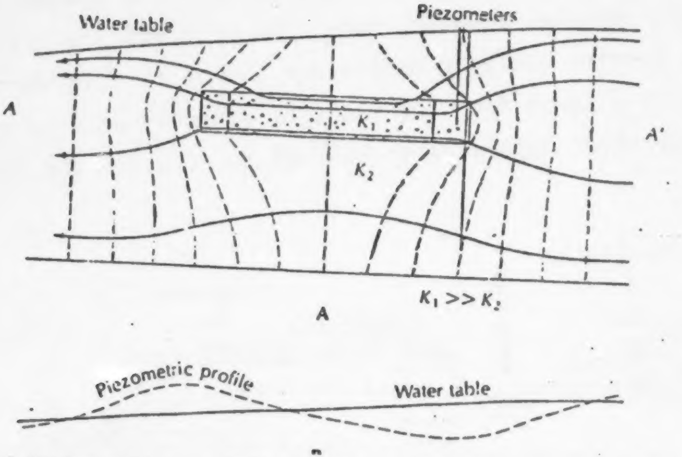

Transpiration
Loess
Water table
Massac Creek
Direct runoff
Evaporation
Water table
Sand
Holly
Springs
Direct runoff
Alluvium
OHIO RIVER
Piezometric surface of water in the Ripley formation
clay
Porters
Creek
Leakage through sandstone dikes
formation
Ripley

Freeze has provided an interesting hypothetical example of the complicated influence of geologic strata on regional groundwater flow patterns. The many different flow paths are a result of the interaction of high permeability layers, no-flux boundary conditions and the various hydraulic gradients operating in the region.


H
V
W
X
Y
Z
F
G
A
B
C
D
E
900
800
700
1000
$K_0 = 100$
$K_0 = 1$
$K_0 = 100$
$K_0 = 1$
$K_0 = 100$
Scale
Meters
40
20
0
Vertical exaggeration 10:1
0
200
400
Meters
Equipotential line (ϕ in cm H_2O)
Flow direction
Water table
$K_{xx}/K_{zz} = 100$ in all formations

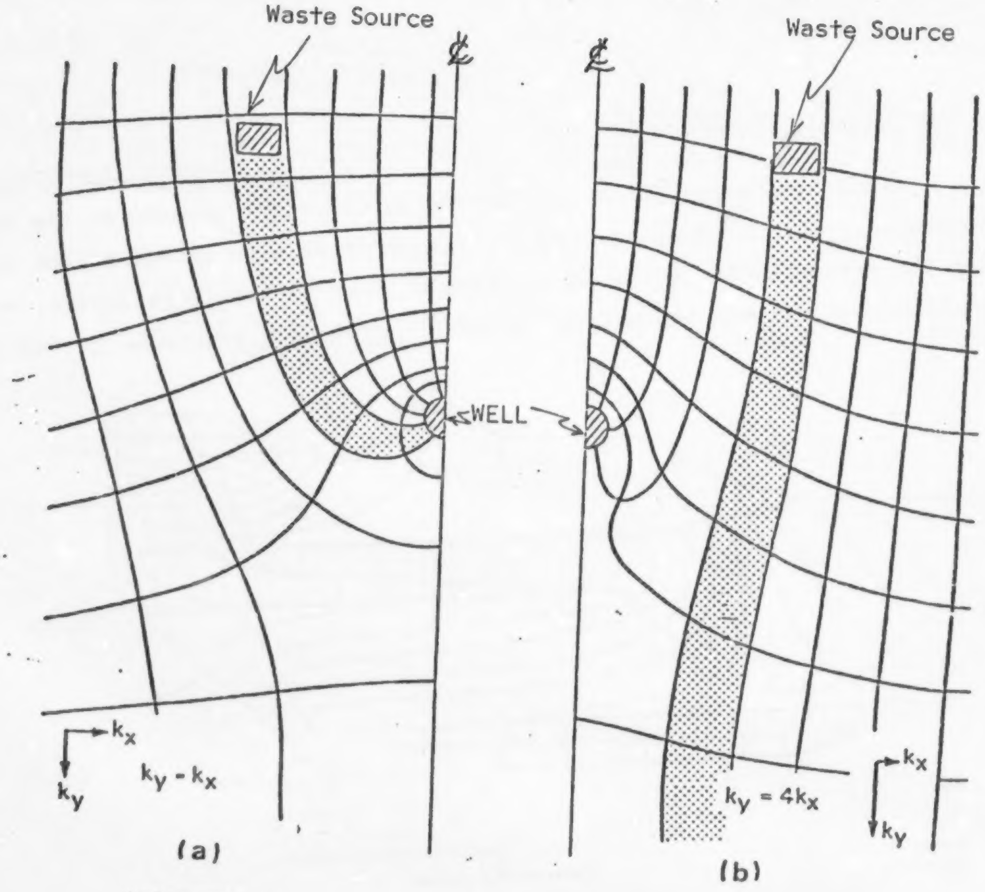
Ref: R.A. Freeze

The Effects of Lenses:


Water table
Piezometers
A
A'
K_1
K_2
A
$K_1 >> K_2$
Piezometric profile
Water table

Ref: Applied Hydrogeology, C.W. Fetter, Charles Merrill Publ. Co., Columbus, OH

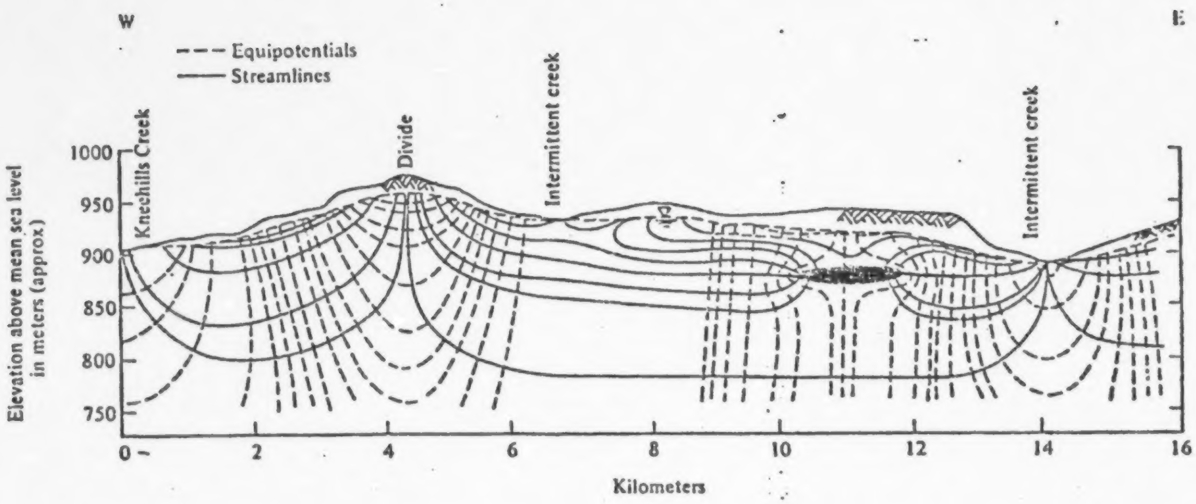
Anisotropic Effects:


Waste Source
℄
℄
Waste Source
WELL
k_x
k_y
$k_y - k_x$
(a)
$k_y = 4k_x$
k_x
k_y
(b)

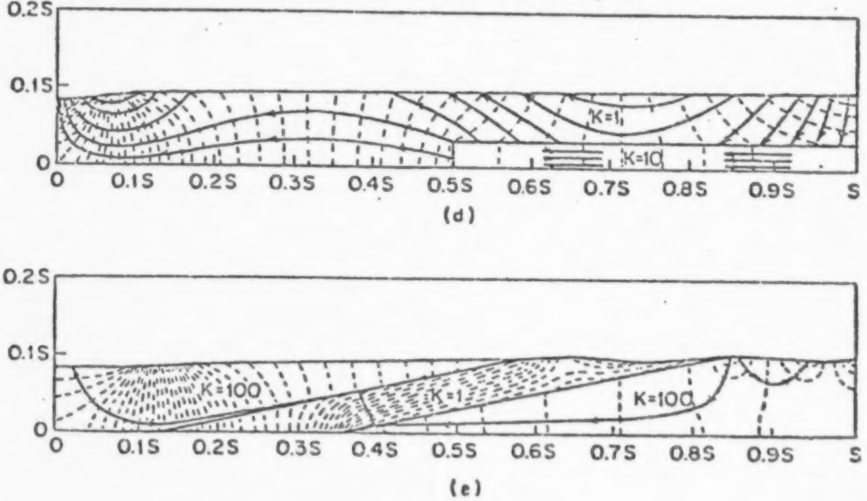
ISOTROPIC

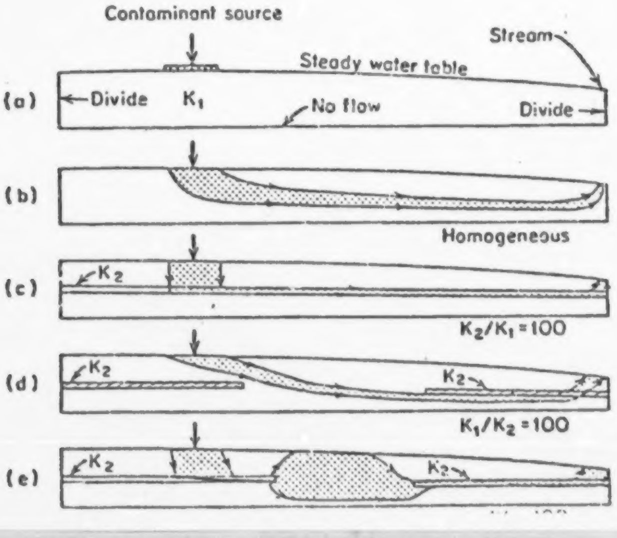
ANISOTROPIC

Ref:"Groundwater Quality--Measurement, Prediction, and Protection, Proceedings of a Conf
Water Research Centre Conference


W
E
Equipotentials
Streamlines
Knechills Creek
Divide
Intermittent creek
Intermittent creek
Elevation above mean sea level in meters (approx)
1000
950
900
850
800
750
0
2
4
6
8
10
12
14
16
Kilometers

Ref: Hydraulics of Groundwater, J. Bear, McGraw-Hill, 1979


0.2S
0.1S
0
K=1
K=10
0
0.1S
0.2S
0.3S
0.4S
0.5S
0.6S
0.7S
0.8S
0.9S
S
(d)
0.2S
0.1S
0
K=100
K=1
K=100
0
0.1S
0.2S
0.3S
0.4S
0.5S
0.6S
0.7S
0.8S
0.9S
S
(e)


Contaminant source
Stream
Steady water table
(a)
Divide
K_1
No flow
Divide
(b)
Homogeneous
(c)
K_2
$K_2/K_1 = 100$
(d)
K_2
K_2
$K_1/K_2 = 100$
(e)
K_2
K_2

WELL DRILLING METHODS

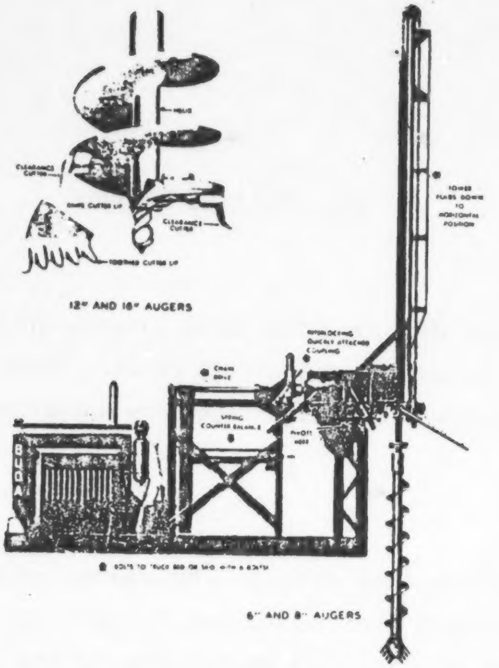
This Appendix discusses the three primary drilling methods for boring test holes and installing monitoring wells. These methods are described and the major advantages/disadvantages are presented.

AUGER BORING

In auger boring, the hole is advanced by rotating continuous helical augers into unconsolidated formations [Figure 1]. The spiral action resulting from the rotation, brings cuttings to the surface. Auger sections with hollow centers or stems are normally used for installing monitoring wells and/or soil sampling at depth. Hollow stems range up to 6.0 in. inside diameter (I.D.), although the 3.0 in. I.D., or slightly larger is most common. During drilling a steel plug is used to prevent intrusion of formation materials into the hollow augers. The plug is positioned by and removed with drill rod which extends to the ground surface.

The 3^+ in. I.D. hollow stem auger is used to install 2.0 in. diameter monitoring wells with standard couplers (PVC or steel) or 3 in. diameter flush coupled well casing and screens. Once the desired well depth is reached, the auger plug is removed, leaving the hollow augers as a temporary casing to prevent hole collapse. The casing and screen assembly is then lowered into the augers. Next, the augers are slowly pulled leaving the well casing in place. In non-cohesive formations, the hole will quickly collapse around the casing upon auger removal. Typical modifications to this installation procedure include:

1. Installing a firm base (gravel or cement) below the well screen.
2. Installing a sandpack in the annular space between the boring well and the well screen.
3. Sealing the borehole above the screen with bentonite clay or cement.
4. Installing a protective surface casing around the well head.


HELIX
CLEARANCE CUTTER
CLEARANCE CUTTER
TOOTHED CUTTER LIP
12" AND 16" AUGERS
TOWER FOLDS DOWN TO HORIZONTAL POSITION
INTERLOCKING QUICKLY ATTACHED COUPLING
CHAIN DRIVE
SPRING COUNTER BALANCE
BUDA
6" AND 8" AUGERS

BUDA EARTH DRILL WITH CONTINUOUS HELICAL AUGERS

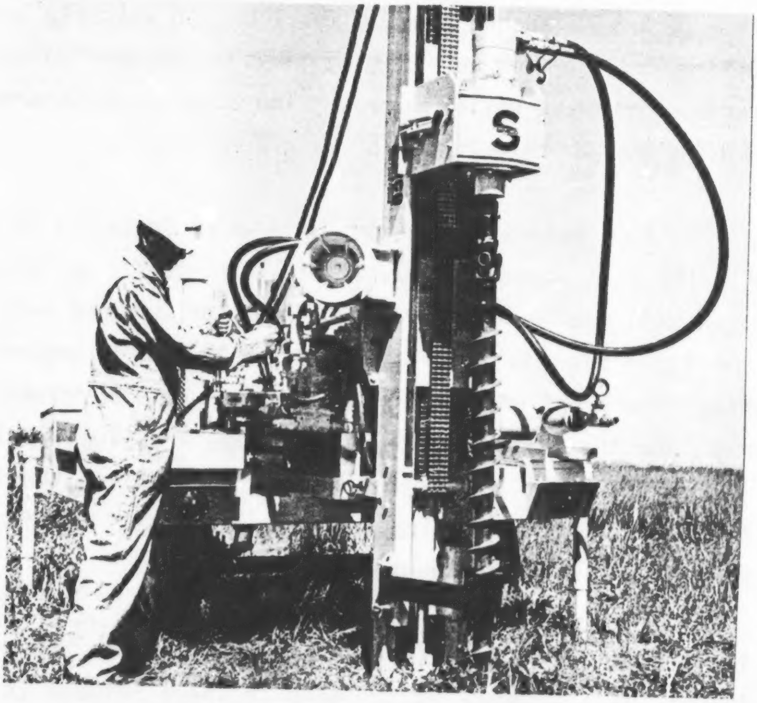


Figure 1
Auger Drilling Equipment

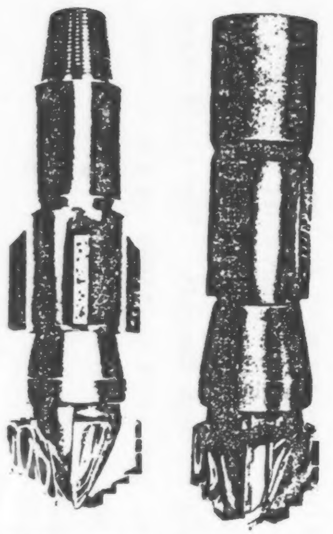
Core sampling over the interval to be occupied be well screen is recommended to ensure that the desired horizon will be monitored.

Advantages	Disadvantages
1. Dry method a. Wells can be sampled immediately after completion and development b. Formation waters can often be sam- during drilling in coarse sediments by advancing a well point ahead of the augers	1. Severe problems in heaving sand situations
2. Fast	2. Limited to depths of 100-150 ft
3. Usually less expensive than rotary or cable tool	3. Can be used only in unconsolidated materials
4. Equipment generally available throughout the U.S.	
5. High-mobility rigs can reach most sites	

HYDRAULIC ROTARY

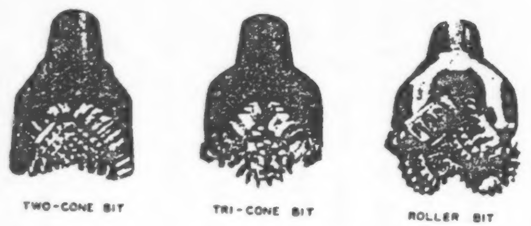
When drilling a hole by the hydraulic rotary method, a rotating bit breaks up the formation and the cuttings are brought to the surface by a recirculating drilling fluid [Figure 2]. With a conventional rig, drilling fluid is pumped from a settling basin, through a water swivel, down the hollow interior of the drill rod, and through the bit. The fluid then flows upward in the annulus, carrying the drill cuttings to the surface. Here, it is discharged into a pit, and the cuttings settle out. At the other end of the pit, the fluid is pumped out to circulate down the drill rod again.

The density and viscosity of the drilling fluid are critical factors for preventing borehole collapse and removing larger or heavy cuttings. For installing monitoring wells, clean water is the preferred drilling fluid. However, for increased viscosity and density, bentonite clay is commonly added to produce a drilling "mud."



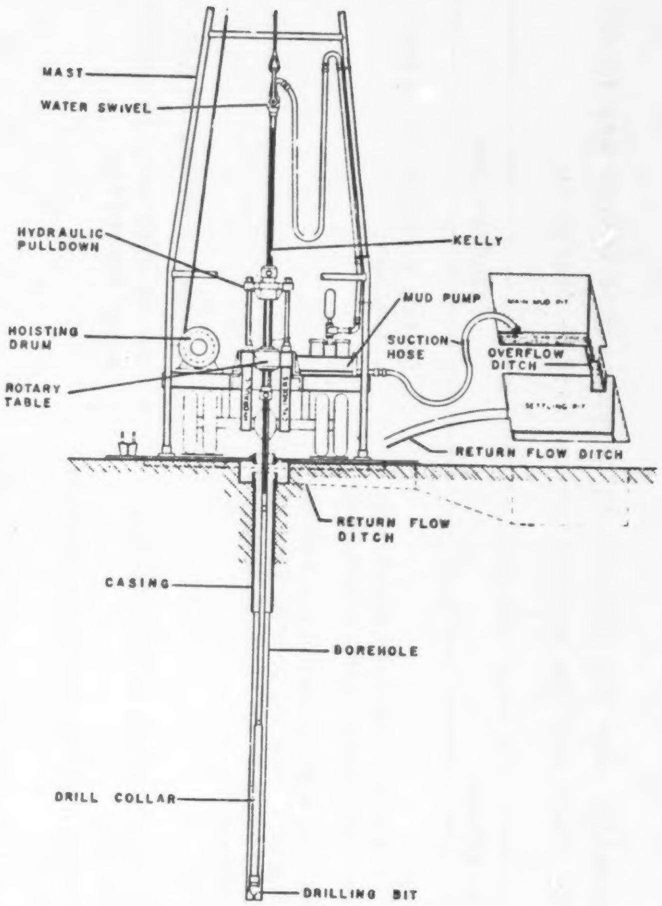
DRAG-TYPE BITS WITH REPLACEABLE BLADES.

(After Johnson, 1972)


TWO-CONE BIT
TRI-CONE BIT
ROLLER BIT

ROCK BITS

(After Hvorslev, 1965)


MAST
WATER SWIVEL
HYDRAULIC PULLDOWN
KELLY
MUD PUMP
HOISTING DRUM
SUCTION HOSE
OVERFLOW DITCH
ROTARY TABLE
RETURN FLOW DITCH
RETURN FLOW DITCH
CASING
BOREHOLE
DRILL COLLAR
DRILLING BIT

(After Hvorslev, 1965)

FIGURE 2. HYDRAULIC ROTARY DRILLING EQUIPMENT

The drill string consists of the bit, a stabilizer, and the drill pipe. Two basic types of bits are used:

- roller bits in rock
- drag bits in unconsolidated materials

Roller bits have conical rollers with hardened steel teeth of various lengths, spacing and shape dependent upon the type of material to be drilled. Some rollers have inset carbide buttons for drilling in hard rock. As the rollers rotate, they crush and chip the formation material. Drag bits have fixed blades, and the cutting edge is surfaced with carbide or some other abrasion-resistant material.

The bit is attached to a heavy weighted section of the drill string called a drill collar or stabilizer. This weight, just above the bit, tends to keep the borehole straight and vertical. The drill rod connects the stabilizer to the kelly. The outside diameter ranges from 2 3/8 to 4 ½ in. The kelly is a fluted or square bar which passes through a rotary table and imparts a rotary motion to the drill string. When the length of the kelly has been drilled, a new section of rod is added and drilling resumed.

Once the desired depth is reached, the drilling tools are removed. In unconsolidated formations, the hole is maintained by the drilling fluid until casing is installed. The method modification presented for augered wells are also common to rotary drilled wells. Consolidated formations often do not require the use of screens.

Advantages	Disadvantages
1. Fast. Wells can be constructed in any geologic formation	1. Diluting formation during drilling precludes representative sampling
2. Disturbed soil samples from known depths if travel time of borehole cuttings is taken into account, although some sorting may occur	2. After well completion drilling fluid must be removed artificially and naturally before reresentative sample can be collected
3. Flexibility in final well construction	3. There is potential for vertical movement in formation stabilizer material placed between casing and borehole wall after completion
4. Can run a complete suite of geophysical well logs	
5. Core samples can be collected	
6. Can be used in unconsolidated sediments and consolidated rocks	

AIR ROTARY

In normal air rotary drilling, a rotating down-hole hammer may be used to break up formation material by percussion, although conventional rotary bits are also used. However, rather than carrying cuttings to the surface with drilling mud, high velocity compressed air is used. Down-hole hammers are essentially the pneumatic hammer type, similar in operation to those used by road repair crews to break up pavement. Drilling rates of 1 to 2 ft per minute are not unusual. Most rigs are equipped with a small mud pump permitting a conventional rotary hole to be drilled through unconsolidated overburden to competent rock. When this hole is finished, casing is set into rock to prevent caving, and drilling continues using the air rotary method. Consequently, less water is required, thereby reducing a logistics problem that can become difficult, especially in arid regions.

A modified version of conventional air rotary, dual-tube reverse air, has been successfully used for preliminary borings and progressive depth groundwater sampling as discucced in Section V. In this method, the drill pipe comprises two concentric tubes. Air and/or fluid is blown down between the pipes to the drill bit. Cuttings and formation water move up the inner pipe at velocities in excess of 3,000 ft/min, thus providing nearly instantaneous samples from the level of the drill bit.

At one study site, more than 15 borings were made down to depths of about 200 ft. Monitoring data from groundwater samples collected at 10 ft intervals were used to select vertical locations for well screns. Samples taken from 3-well nests installed at each boring location validated data obtained from the preliminary borings.

Advantages	Disadvantages
1. Brings a continuous representative sample of water and formational material to the surface	1. Not commont type of drilling rig on a nationwide basis
2. No fluid loss to dilute or contaminate formation water	2. Requires considerable skill to operate equipment in unconsolidated formation
3. Can provide data on potential yield of individual aquifers or beds during drilling	3. May not be economical for small jobs
4. No need for drilling mud and ample water supplies	
5. Very fast	
6. Can drill both consolidated and unconsolidated formations	

CABLE-TOOL (PERCUSSION)

In cable-tool or precussion drilling, the hole is deepened by regularly lifting and dropping a heavy string of drilling tools in the borehole [Figure 3]. The drill bit breaks or crushes hard rock into small fragments and in soft, unconsolidated sediments loosens the material. The up-and-down action of the drill string mixes the crushed or loosened particles with water to form a slurry. If no water is present in the formation being penetrated, water is added to the borehole. Cuttings are allowed to accumulate until they start to lessen the impact of the bit and then are removed with a bailer or sand pump.

A cable-tool drill string consists of three units:

- the drill bit,
- drill stem,
- rope socket.

The bit provides the cutting edge of the drill string, the action of which is increased by the weight of the drill stem. This weight also acts as a stabilizer, keeping the hole straight. The rope socket connects the string of tools to the cable and allows the tools to rotate slightly with respect to the cable.

The cuttings/water slurry is removed from the borehole with a "bailer." The bailer consists of a section of pipe with a check valve at the bottom and is filled by an up-and-down motion in the bottom of the hole. Each time the bailer is dipped, the valve opens, allowing the cuttings slurry to move into it. The up-and-down motion is continued until the bailer is full. At this point, it is brought to the surface and the contents dumped on the ground or contained, as required. The sand pump is a bailer that is fitted with a plunger so that an upward pull on the plunger tends to produce a vacuum that opens the valve and sucks sand or slurried cuttings into the tubing.

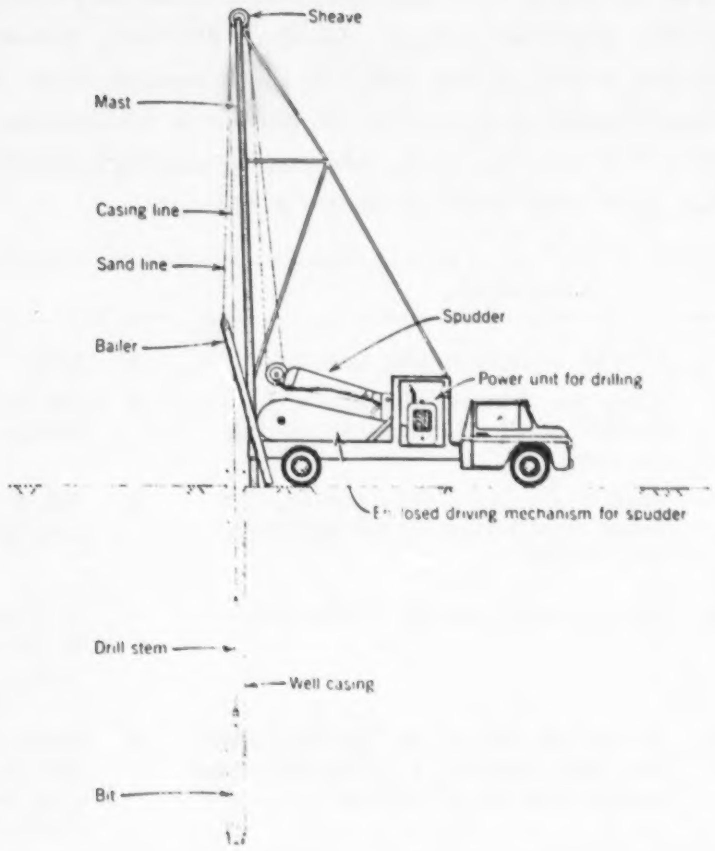

Sheave
Mast
Casing line
Sand line
Bailer
Spudder
Power unit for drilling
Enclosed driving mechanism for spudder
Drill stem
Well casing
Bit

FIGURE 3. SIMPLIFIED CABLE TOOL PERCUSSION RIG

(After Davis & De Wiest, 1966)

Casing is driven by attaching a drive clamp to the drill stem; the reciprocal action of the rig hammers the casing into the ground as the clamp makes contact with the drivehead on top of the casing. The operation can be speeded by drilling ahead of the casing but only if the hole will stay open by itself. If when drilling an open hole there is a cave in, the drill string could be trapped. Cautious drillers, therefore, rarely drill ahead of the casing unless they are going through rock. Normal procedure in unconsolidated sediments is to drive the casing into the formation and then to clean out the inside the casing with the drill tools. This is slower but safer than drilling ahead of the hole.

Advantages	Disadvantages
1. Simple equipment and operation.	1. Slow.
2. Good seal between casing and formation if flush joint casing is used.	2. Use of water during drilling can dilute formation water.
3. Good disturbed soil samples. Known depth from which cuttings are bailed.	3. Potential difficulty in pulling casing in order to set screen.
4. Core samples can be collected.	4. No formation water samples can be taken during drilling unless open-ended casing is pumped, or a screen set.
5. If casing can be bailed dry without sand heaves, a formation-water sample can be collected.	5. Heavy steel drive pipe is used and could be subject to corrosion under adverse contaminant characteristics.
6. Can be used in unconsolidated sediments and consolidated rocks.	6. Cannot run a complete suite of of geophysical well logs because of casing.
7. Only small amounts of water are required for drilling.	
8. Once water is encountered, changes in static or potentiometric levels are readily observable.	

APPENDIX E

AIR SAMPLING EQUIPMENT FOR VOLATILE ORGANICS

PARTS

1. SAMPLE COLLECTION
2. SAMPLE TRAP PREPARATION

PART 1

Volatile Organic Air Pollutant Analysis
Sample Collection
January 1980

1.0 Introduction

1.1 Sampling for organics in air is performed by drawing air through a glass tube packed with the porous polymer resin Tenax GC. Air is drawn through each trap at 0.1 to 1 liter per minute using a calibrated personnel sampler. The sampler is calibrated before sampling using a mass flow meter.

2.0 Equipment

2.1 Sampler. MSA model S or equivalent personnel sampler. Capable of adjusting and monitoring the flow over the range of 0.1 to 1 liter per minute (lpm) with a trap in place.

2.2 Mass flow meter. Portable unit equipped with a teflon fitting to measure the flow through a sampling trap. It should have a range of 0 - 2 lpm and 0 - 10 lpm.

2.3 Sample traps. Glass sampling traps packed with Tenax GC.

2.4 Sampling line. 2 - 5 feet of 1/4" o.d. tygon tubing with a teflon fitting at one end to attach to the sampling traps.

2.5 Dummy Sampling Trap. One trap taken from the batch to be sampled.

3.0 Calibration Procedure

3.1 Attach the dummy sampling trap to the sample pump. Attach the mass flow meter over the inlet of the sample trap. Set the mass flow meter to the appropriate range and zero with no flow.

3.2 Start the sampling pump and adjust for a stable flow at the desired rate. Note the flow meter reading on the personnel sampler at the desired flow rate.

3.3 Record the mass flow meter reading and the sampler flow meter reading.

3.4 Detach the mass flow meter and the dummy trap.

3.5 Recalibrate the sample pump at the beginning of each sampling day, whenever the sample flow meter reading deviates from that at calibration or whenever necessary.

3.6 Flow rate variation between these traps is less than 5%.

4.0 Sample Collection

4.1 Using a clean tissue or wearing a nylon cloth glove, remove a sample trap from its culture tube being careful to reseal the culture tube.

4.2 Inspect the trap for damage such as broken glass, glass wool plugs loose or resin spilled. If the trap is in question, replace in culture tube and return to the laboratory unused.

4.3 Attach the trap to the calibrated sampler. See Figure 1.

4.4 Begin sampling noting the start time and sample pump flow meter reading. Collect sample volumes depending upon the suspected levels of contaminants. Generally:

Wells/boreholes:	1 @ 1 lpm for 5-30 min.
Dumpsites:	1 @ 100 ml/min for 60 min and 1 @ 1 lpm for 60 min.
Offsite:	1 @ 100 ml/min for 60 min and 1 @ 1 lpm for 60 min.

4.5 Stop sampling noting the end time and sample pump flow meter reading. Replace the trap into the culture tube being sure the glass wool cushions the trap. Reseal with the teflon lined septum cap and tag.

4.6 Replace sample traps in culture tubes into the tin can and reseal the can. Be sure to tag the "field blank" and "field spike" samples in each tin can.

5.0 Quality Control

5.1 Sample pumps are calibrated daily and any flow rate changes noted by monitoring the flow meter on the sampler.

5.2 Contamination in each sample transport container is monitored by a "field blank".

5.3 Deterioration of the samples is monitored by a "field spike".

6.0 Options

6.1 In the event of unknown atmospheres suspect of containing high levels of contaminants, two samples should be collected at flow rates of 1 and 1/10 or 1/100 rate (1 lpm and 10 ccpm for example).

7.0 Limitations

7.1 The sample traps are essentially short chromatographic columns. Retention of chemicals is dependant upon absorbtion characteristics of the chemical/resin system. Factors influencing retention include: temperature, flow rate, air volume and vapor pressure of the chemical. Volatile species like vinyl chloride are only moderately retained while other chemicals like chlorobenzene are retained very well. All chemicals will experience breakthrough under the correct conditons however. Table I lists breakthrough volumes for some relevant chemicals. The volumes represent the amount of air sampled where 50% of the collected chemical is lost through the trap. Data for chemicals where the sample volume exceeded the breakthrough volume represent at least that amount in the air.

8.0 References

8.1 "Development of Analytical Techniques for Measuring Ambient Atmospheric Carcinogenic Vapors", EPA-600/2-75-075, November 1975.

8.2 Env. Sci. Tech., 9, 556 (1975).

8.3 Pellizzari, E. D., Quarterly Report No. 1, EPA Contract No. 68-02-2262, February 1976.

8.4 Anal. Lett., 9, 45 (1976).

PREPARED 1/24/8 O. J. [illegible]

E1-4

Table I

Table A-2. TENAX GC BREAKTHROUGH VOLUMES FOR SEVERAL ATMOSPHERIC POLLUTANTS[1]

liters of air sampled

Chemical Class	Compound	b.p. (°C)	Temperature (°F) 50	60	70	80	90	100
Halogenated hydrocarbon	methyl chloride	-24	8	6	5	4	3	2.5
	methyl bromide	3.5	3	2	2	1	1	0.9
	vinyl chloride	13	2	1.5	1.25	1.0	0.8	0.6
	methylene chloride	41	11	9	7	5	4	3
	chloroform	61	42	31	24	18	13	10
	carbon tetrachloride	77	34	27	21	16	13	10
	1,2-dichloroethane	83	53	41	31	23	18	14
	1,1,1-trichloroethane	75	23	18	15	12	9	7
	tetrachloroethylene	121	361	267	196	144	106	78
	trichloroethylene	87	90	67	50	38	28	21
	1-chloro-2-methylpropene	68	26	20	16	12	9	7
	3-chloro-2-methylpropene	72	29	22	17	13	10	8
	1,2-dichloropropane	95	229	162	115	81	58	41
	1,3-dichloropropane	121	348	253	184	134	97	70
	epichlorohydrin (1-chloro-2,3-epoxypropane)	116	200	144	104	74	54	39
	3-chloro-1-butene	64	19	15	12	9	7	6
	allyl chloride	45	21	16	12	9	6	5
	4-chloro-1-butene	75	47	36	27	20	15	12
	1-chloro-2-butene	84	146	106	77	56	40	29
	chlorobenzene	132	899	653	473	344	249	181
	o-dichlorobenzene	181	1,531	1,153	867	656	494	372
	m-dichlorobenzene	173	2,393	1,758	1,291	948	697	510

(continued)

Table A-2 (cont'd.)

Table I cont

Chemical Class	Compound	b.p. (°C)	Temperature (°F) 50	60	70	80	90	100
Halogenated hydrocarbons (cont'd)	benzyl chloride	179	2,792	2,061	1,520	1,125	830	612
	bromoform	149	507	386	294	224	171	131
	ethylene dibromide	131	348	255	188	138	101	74
	bromobenzene	155	2,144	1,521	1,079	764	542	384
Halogenated Ethers	2-chloroethyl ethyl ether	108	468	336	241	234	124	89
	Bis-(chloromethyl)ether	-	995	674	456	309	209	142
Nitrosamines	N-nitrosodimethylamine	151	385	280	204	163	148	107
	N-nitrosodiethylamine	177	2,529	1,836	1,330	966	700	508
Oxygenated hydrocarbons	acrolein	53	19	14	10	8	6	4
	glycidaldehyde	-	364	247	168	114	77	52
	propylene oxide	34	35	24	17	11	8	5
	butadiene diepoxide	-	1,426	1,009	714	506	358	253
	cyclohexene oxide	132	2,339	1,644	1,153	811	570	400
	styrene oxide	194	5,370	3,926	2,870	2,094	1,531	1,119
	phenol	183	2,071	1,490	1,072	769	554	398
	acetopheonone	202	3,191	2,382	1,778	1,327	991	740
	β-propiolactone	57	721	514	366	261	186	132
Nitrogenous Hydrocarbons	nitromethane	101	45	34	25	19	14	11
	aniline	184	3,864	2,831	2,075	1,520	1,114	817
Sulfur Compounds	diethyl sulfate	208	40	29	21	15	11	8
	ethyl methane sulfate	86	5,093	3,681	2,564	1,914	1,384	998

(continued)

Table I cont

Table A-2 (cont'd.)

Chemical Class	Compound	b.p. (°C)	Temperature (°F) 50	60	70	80	90	100
Amines	dimethylamine	7.4	9	6	4	3	2	1
	isobutylamine	69	71	47	34	23	16	11
	t-butylamine	89	6	5	4	3	2	1
	di-(n-butyl)amine	159	9,506	7,096	4,775	3,105	2,168	1,462
	pyridine	115	378	267	189	134	95	67
	aniline	184	8,128	5,559	3,793	2,588	1,766	1,205
Ethers	diethyl ether	34.6	29	21	15	11	8	5
	propylene oxide	35	13	9	7	5	4	3
Esters	ethyl acetate	77	162	108	72	48	32	22
	methyl acrylate	80	164	111	75	50	34	23
	methyl methacrylate	100	736	484	318	209	137	90
Ketones	acetone	56	25	17	12	8	6	4
	methyl ethyl ketone	80-2	82	57	39	27	19	13
	methyl vinyl ketone	81	84	58	40	28	19	14
	acetophenone	202	5,346	3,855	2,767	2,000	1,439	1,037
Aldehydes	acetaldehyde	20	3	2	2	1	0.9	0.7
	benzaldehyde	179	7,586	5,152	3,507	2,382	1,622	1,101
Alcohols	methanol	64.7	1	1	0.8	0.6	0.4	0.3
	n-propanol	97.4	27	20	14	10	7	5
	allyl alcohol	97	32	23	16	11	8	6

(continued)

Table I cont.

Table A-2 (cont'd.)

Chemical Class	Compound	b.p. (°C)	Temperature (°F) 50	60	70	80	90	100
Aromatics	benzene	80.1	108	77	54	38	27	19
	toluene	110.6	494	348	245	173	122	86
	ethylbenzene	136.2	1,393	984	693	487	344	243
	cumene	152.4	3,076	2,163	1,525	1,067	750	527
Hydrocarbons	n-hexane	68.7	32	23	17	12	9	6
	n-heptane	98.4	143	104	75	55	39	29
	1-hexene	63.5	28	20	15	11	8	6
	1-heptene	93.6	286	196	135	93	64	44
	2,2-dimethylbutane	49.7	0.5	0.4	0.3	0.2	0.2	0.1
	2,4-dimethylpentane	80.5	435	252	146	84	49	28
	4-methyl-1-pentene	53.8	14	10	8	6	4	3
	cyclohexane	80.7	49	36	26	19	14	10
Inorganic gases	nitric oxide	-	0	0	0	0	0	0
	nitrogen dioxide	-	0	0	0	0	0	0
	chlorine	-	0	0	0	0	0	0
	sulfur dioxide	-	0.06	0.05	0.03	0.02	0.02	0.01
	water	100	0.06	0.05	0.04	0.03	0.01	0

[a] Breakthrough volume is given in ℓ/2.2 g Tenax GC used in sampling cartridges.

from: EPA-560/13-79-010, September 1974
"Analytical Protocols for Making a Preliminary Assessment
of Halogenated Organic Compounds in Man and
Environmental Media".

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Sample Collection

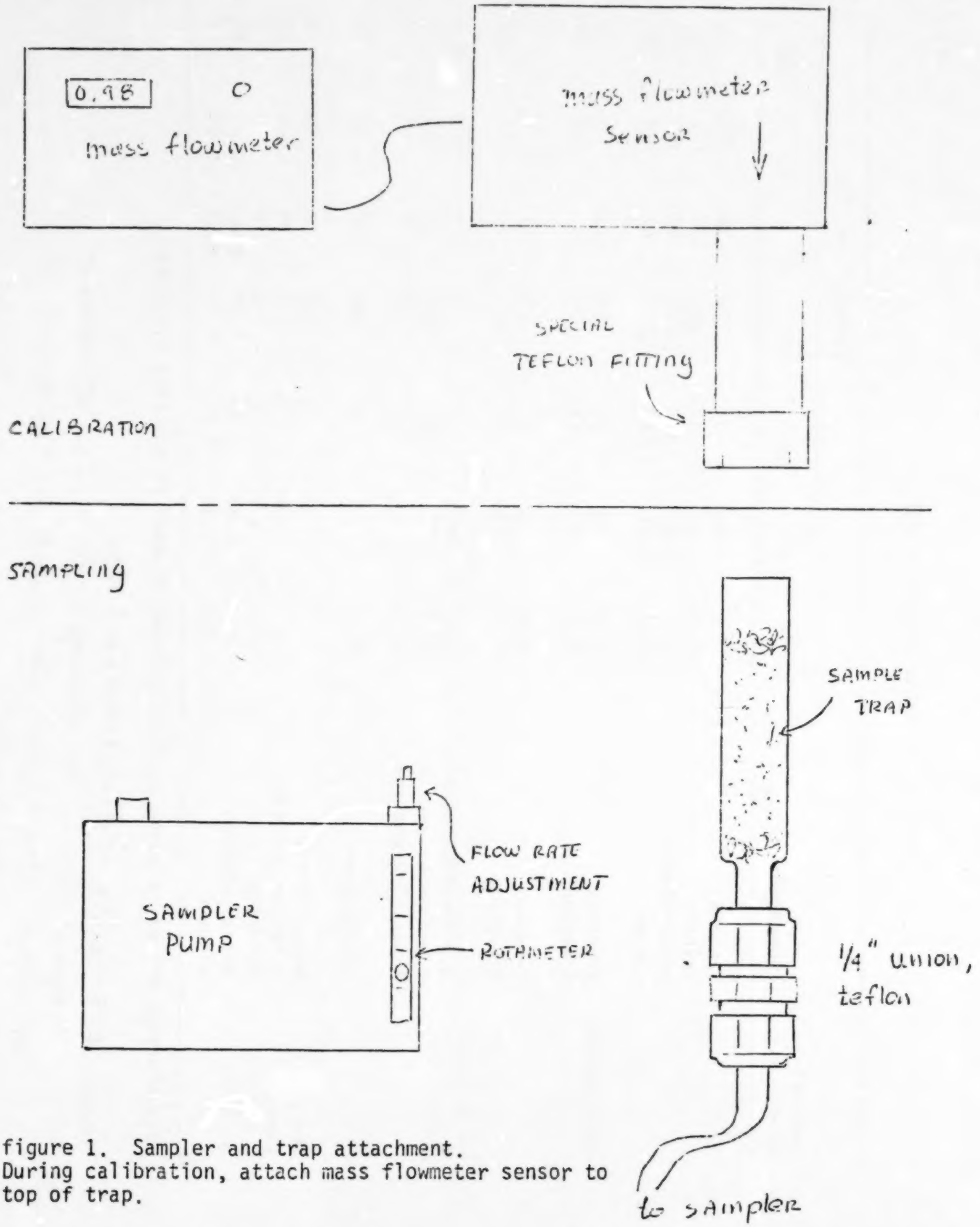
0.98
mass flowmeter
mass flowmeter Sensor
SPECIAL TEFLON FITTING
CALIBRATION
SAMPLING
SAMPLE TRAP
FLOW RATE ADJUSTMENT
SAMPLER PUMP
ROTHMETER
1/4" union, teflon
to sampler

figure 1. Sampler and trap attachment.
During calibration, attach mass flowmeter sensor to top of trap.

PART 2

Volatile Organic Air Pollutant Analysis
Sample Trap Preparation
January 1980

1.0 Introduction

1.1 Sampling for organics in air is performed by drawing air through a glass tube packed with the porous polymer resin Tenax GC. The traps and resin must be thoroughly cleaned before use to minimize the trap background. Clean traps ready for field use must also be carefully packed in clean glass tubes to avoid contamination during handling.

2.0 Materials

2.1 Glass sampling traps. Pyrex glass traps constructed as shown in Figure 1.

2.2 Resin. Tenax GC, 35/60 mesh.

2.3 Glass wool.

2.4 Culture tubes. Pyrex glass screw cap tubes 25 mm x 110 mm. Pyrex 9825 or equivalent.

2.5 Teflon backed silicone septa. Pierce 12722 or equivalent.

2.6 Bakelite screw caps to fit culture tubes. Pierce 13219 or equivalent.

2.7 Dessicator. Glass dessicator with activated charcoal adsorbant.

2.8 Quart paint cans with pressure fit lids.

3.0 Resin Preparation

3.1 Extract new and used Tenax GC with methanol followed by pentane in a soxhlet extractor. Extract with each solvent at least 6 hours.

3.2 Dry the resin under vacuum for at least 4 hours.

3.3 Sieve the dried resin to the 35/60 mesh particle size range.

3.4 Seal the cleaned and sieved resin in a glass jar capped with a teflon liner. Store in a dessicator containing activated carbon.

4.0 Trap and Container Cleanup

4.1 Wash new and used glass sampling traps and culture tubes with lab soap and hot tap water. Rinse at least three times with organics free water (Millipore or equivalent). Rinse with methanol and let air dry.

4.2 Bake the cleaned tubes in an oven at 220°C for at least 1 hour. Remove from the oven and store in a dessicator containing activated carbon.

4.3 Wash glass wool with methanol, air dry and bake in an oven at 220°C for at least 1 hour. Remove from the oven and store in a dessicator containing activiated charcoal.

4.4 Bake teflon backed septa in an oven at 80°C for 30 minutes. Remove from the oven and store in a dessicator containing activated charcoal.

4.5 Bake paint cans in oven at 100°C for 1 hour.

5.0 Trap Preparation

5.1 Pack about a 1 cm plug of glass wool into the trap followed by 6 cm of cleaned Tenax GC. Lightly tap the trap on the bench to pack the resin. Add another 1 cm glass wool plug to hold the resin in place.

5.2 Condition each trap at 270°C with 20-30 ml/min helium flowrate for 30 minutes.

5.3 Remove the hot trap and place into a culture tube with a glass wool plug to cushion the trap. Immediately cap the tube with a teflon lined septum cap. Store the tubes in batches of 7 traps in quart paint cans.

6.0 Quality Control

6.1 Prior to sending traps to the field, remove one trap from each paint can and analyze it for contaminants. If the traps are clean, the batch is acceptable for use. Mark the trap "Field blank - label and return" and replace it in the can.

6.2 Prior to sending traps to the field, remove one trap from each paint can and spike with known amounts of chemicals from the permeation tube system. Mark the trap "Field spike - label and return" and replace it in the can.

7.0 Options

7.1 Traps with longer resin beds may be packed in order to increase the retention volumes of pollutants.

8.0 References

8.1 "Selection and Evaluation of Sorbant Resins for the Collection of Organic Compounds", EPA-600/7-77-044, April 1977.

8.2 "Development of Method for Carcinogenic Vapor Analysis in Ambient Atmospheres", EPA-650/2-74-121, July 1974.

prepared 1/24/80 O.J. Logsdon II

Attachment to: Sample Trap Preparation

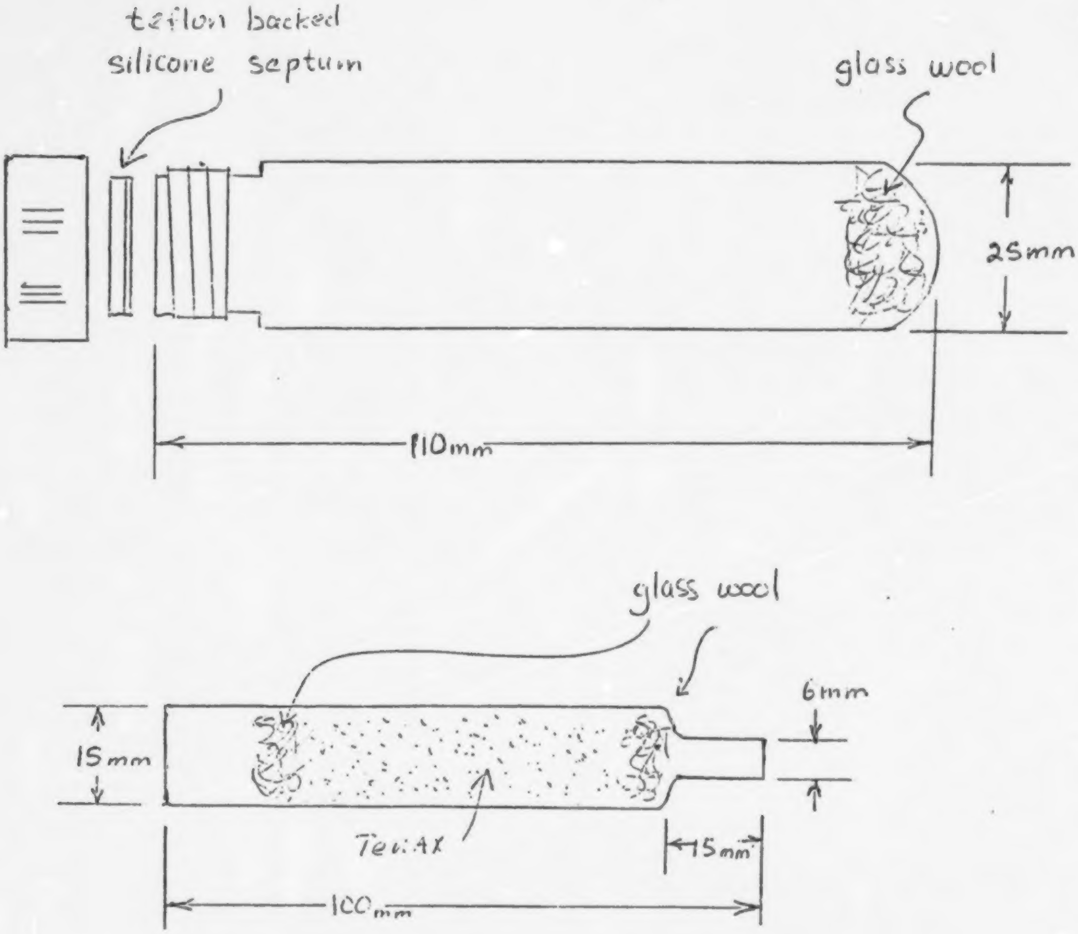
teflon backed
silicone septum
glass wool
25mm
110mm
glass wool
6mm
15mm
Tenax
15mm
100mm

figure 1. Sampling trap and culture tube holder design.

APPENDIX F

EXAMPLES OF EASEMENTS

CONSENT FOR ACCESS TO PROPERTY

NAME: ______________________________

ADDRESS: ______________________________

I hereby give my consent to officers, employees, authorized representatives and persons acting at the request of the United States Environmental Protection Agency (EPA) to enter and have access to my property located at the above address for the following purposes:

1. the detection of subsurface metal and subsequent staking or otherwise identifying locations of any such subsurface metal detected;
2. the drilling of holes for subsurface investigation including the use of drilling rigs;
3. the taking of such soil, water and air samples as my be determined to be necessary; and
4. other actions related to the investigation of surface of subsurface contamination.

EPA ensures that upon completion of monitoring, all material and equipment will be removed from the property, and the property will be restored, as nearly as possible, to its original condition.

______________________ Date

______________________________ Signature

WITNESSES:

______________________________ Date ______________________

______________________________ Date ______________________

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT
NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
BUILDING 53, BOX 25227, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

DATE: November 25, 1980

Mr. Joe Jonker
Western Terminal Company
700 South Flower Street
Denver, Colorado 80228

Dear Mr. Jonker:

This letter confirms our telephone conversation of November 12, 1980, regarding EPA's investigation of property which adjoins property owned by Western Terminal Company at Ormond Street, Oxnard, Colorado.

In the course of our conversation and pursuant to my request, you granted permission for representatives of EPA to enter upon property owned by Western Terminal Company adjacent to property owned by Acme Engineering Company. You agreed that EPA's representatives could drill test wells on Western Terminal Company's property to analyze for possible groundwater migration of pollutants from Acme.

The investigation of Acme is scheduled to take place during the week of December 8, 1980. We expect that six test wells would be drilled on your property during this week. These test wells will be approximately six inches in diameter, will extend to a depth of no more than ten feet below the natural surface of the ground, and will be filled in with appropriate material when sampling is complete. We have checked with the Huerfano County Public Health Department and have been informed that no permits will be required by them for these wells. We are submitting an application for a permit to the South Central Regional Commission although they have not determined that a permit is necessary.

If you concur with this letter, please countersign it in the space below and return it to me. A stamped return envelope is enclosed for your convenience. Your cooperation in this matter is greatly appreciated.

If there is anything which you wish to discuss further concerning this matter, please contact me at 555/556-8000.

Sincerely yours,

Edmund Barrister
Attorney-Advisor
Water Branch
Enforcement Division

Joe Jonker
Western Terminal Company

LICENSE AGREEMENT

This LICENSE AGREEMENT made this ____ day of __________________, 1979, by and between SCOTT COUNTY, IOWA, BOARD OF SUPERVISORS, and the UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA):

WITNESSETH, that:

WHEREAS, EPA has requested permission from Scott County Board of Supervisors to enter upon property owned by Scott County, Iowa, in and in the vicinity of the Scott County Regional Industrial Park in Davenport, Iowa, for the purpose of constructing, operating, and maintaining eleven monitoring wells; and

WHEREAS, the Scott County Board of Supervisors is willing to grant EPA a revocable license for the purposes aforesaid;

NOW, THEREFORE, in consideration of and conditioned upon the mutual covenants, promises, and agreements stated herein, the parties agree as follows:

1. The Scott County Board of Supervisors hereby grants to EPA a revocable license to enter upon the following properties owned by Scott County, Iowa, in and in the vicinity of the Scott County Regional Industrial Park for the purposes to be described.

Property A. This license will allow EPA or its authorized representative to enter upon a corridor 25 feet wide along the western property line of lot 4 in the Scott County Regional Industrial Park for the purpose of constructing, operating, and maintaining one monitoring well in the extreme northwestern corner of said lot.

Property B. This license will allow EPA or its authorized representative to enter upon property leased to the Scott County Landfill Commission in the vicinity of the Scott County Regional Industrial Park for the purpose of constructing, operating, and maintaining ten monitoring wells to be located around the perimeter of the closed eastern most landfill cell.

2. Ingress and egress to and from the wells installed to the extent required over or across property owned by Scott County, Iowa, will be accomplished as deemed necessary by EPA or an authorized representative without prior notification of the Scott County Board of supervisors until this license is terminated.

3. EPA covenants and agrees that upon completion of the monitoring and tests to be performed, that, at the request of the Scott County Board of Supervisors, all material and equipment shall be removed from the properties and said properties will be restored as nearly as possible to its original state and condition.

4. EPA shall have sole responsibility for obtaining any and all necessary permits and/or licenses to conduct construction, maintenance, and test activities in the area involved.

5. This license shall be revocable 60 days after written notice is given by the Scott County Board of Supervisors, but in any event shall terminate and become null and void two years from the date first above stated, unless the license herein granted is extended or renewed by the parties hereto. Any such extension shall be in writing, signed by the parties hereto. Notwithstanding any statements made herein, those obligations undertaken by EPA which by their nature should survive termination or revocation, shall be deemed to survive any such revocation or termination.

6. It is mutually understood that activities undertaken in accordance with this agreement shall not interfere with the rights and obligations included in the leasing agreement entered into by the Scott County Board of Supervisors and the Scott County Landfill Commission on ________________________.

SCOTT COUNTY BOARD OF SUPERVISORS

By________________________________

UNITED STATES ENVIRONMENTAL
PROTECTION AGENCY

By________________________________

APPENDIX G

DRILLING SAFETY PROCEDURES

During the spring of 1980, EPA Region IV personnel were searching for a buried hazardous waste dump in a suburb of Memphis by drilling test holes. The nature of wastes that might be encountered was totally unknown. Consequently, the Region developed a very rational set of "Drilling Safety Procedures", which are presented here in a slightly modified form. About the only thing that could have been done to provide more protection to the drillers and EPA personnel is package them in "moon suits".

Of course, these procedures are not recommended for work at all sites; other sites would probably require less equipment and standby help. The example does provide a starting point for planning since many possible precautions were used. By deleting unnecessary precautions for a particular study site, a fairly good set of tailored precedures can be written .

PROCEDURE FOR MEMPHIS STUDY

Zones of Safety

The drilling site (i.e., the hole being drilled) will be the center of the safety zones. The first zone of safety will be a 50 ft radius from the drill hole. The second zone of safety will be between this 50 ft circle and a 300 ft radius circle.

At the drill rig, there will be a minimum number of personnel. There will be an EPA person with the drilling crew to monitor their general health and physical behavior patterns, and vapors emanating from the bore hole.

At the boundary of the "first zone of safety," there will be an EPA person, an Emergency Medical Team (EMT) Unit, and Civil Defense personnel. Within the "first zone of safety," all unncessary personnel will be evacuated. Each time the drilling rig moves to a different location, the safety zones will move.

At the boundary of the "second zone of safety," there will be a backup EMT Unit, a Fire Department Unit, and additional Civil Defense personnel. The routine of persons outside the "second zone of safety" will not be interrupted unless a sudden unexpected release of gas or liquid is experienced from the drill hole.

The prevailing wind will be monitored by the EPA On-Scene Coordinator (OSC) continually for possible evacuation routes should an immediate evacuation of large scope be necessary.

Protective Procedures

The personnel within the "first zone of safety" will require more protective articles than anyone else. Their protection will be breathing devices and protective clothing. The drill operators and the EPA person should be in full-face mask with an organic vapor cartridge attached during all operation of the drilling rig. Self-contained breathing apparatus (SCBA) is to be available to every individual inside of the first zone. Each individual will have protective coveralls, rubber boots, and gloves on. There will be a practice with the SCBA every morning before drilling begins.

At the outer boundary of the "first zone of safety" personnel equal to the number at the drilling rig will have donned SCBA for use in an emergency to retrieve anyone overcome with fumes.

There will be radio communication maintained with the EPA person at the drill rig, the EPA person at the boundary of the "first zone of safety". The radio will be used to alert those involved with the beginning of drilling, any gas release from the hole, and a medical emergency. Any unauthorized person inside of the second zone will necessitate the stopping of drilling until the situation is again clear.

The EMT units and the fire department unit will be on standby to provide medical transportation for chemically-affected people, and to provide a means of decontamination for anyone splashed by chemicals.

Sampling will be done by EPA (NEIC). The sample will be taken from the drilling rig to the outer boundary of the first zone of safety for preparation. The EPA person at the drilling rig will alert the sampling team to the time for access to the rig for sample retrieval.

Should any drill hole leak gases of any kind or any detectable amounts at any time, that hole should immediately be abandoned until all persons in the first zone of safety can replace the organic breathing masks with the SCBA.

CLOSURE

Each hole drilled will be backfilled with an approved material (cuttings and/or bentonite) prior to drilling the next hole, either by EPA or the contractor.

COORDINATION AND EQUIPMENT

The Federal OSC will serve as the safety coordinator for the sampling and drilling operations. Performance of drilling and sampling will be by either EPA personnel or EPA contract.

The State Civil Defense and the Police will coordinate the evacuation and crowd control around the drilling site.

EPA's Environmental Emergency Branch (EEB) will furnish protective equipment recommended in this safety program, except boots and gloves for the rig operators, unless they wish to furnish their own. Respiratory equipment, fit testing of non-certified personnel (i.e. drillers) will be performed by the EEB representatives.